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CHARACTERISTICS OF BENTHIC ALGAL COMMUNITIES IN THE UPPER GREAT LAKES

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FOREWORD

The Great Lakes, because of their great size and long retention time respond in slow and subtle ways to the stresses placed upon time by man. Very often this great resource is adversely affected with the changes going undetected for many years. These changes are difficult to detect because only certain portions of the ecosystem are ever examined at any one time. Even when many trophic levels are examined, historic data bases are not available to the investigator to look at longterm trends. One of the responsibilities of the Environmental Protection Agency is to assess the ecosystem and how it has been impacted by man. This study on the benthic algae at the lakes provides a historic background for many of the populations. Many old collections were examined to determine the changes that have occurred to date and to document the species that are present so that longterm population trends can be determined.

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ABSTRACT

The upper Great Lakes contain a diverse array of benthic algal communities. Characteristic communities occupy substrates from the supralittoral to depths in excess of 30 m. Diatoms are the dominant taxonomic group present in terms of numbers, and usually in terms of biomass, except in eutrophic areas. Communities in areas receiving minimal direct anthropogenic impact are extremely diverse in terms of both species richness and population evenness. The populations which comprise these communities are generally reported from extremely oligotrophic habitats. A significant number of populations found in undisturbed habitats in the upper Great Lakes have not been previously reported from North America. Benthic communities in more eutrophic areas are characterized by a greater abundance of eurytopic and widely distributed taxa. Many of these species are familiar elements of the floras of smaller, mesotrophic to eutrophic lakes. The communities of directly impacted areas contain a more limited suite of very tolerant populations, usually occurring in high abundance. Species usually reported from saline inland waters or brackish water are a conspicuous element of the flora in highly disturbed regions. Within any given trophic range species richness is further modified by physical factors of the environment and substrate availability. Community diversity is generally reduced at exposed sites where high turbulence apparently reduces colonization potential for some taxa. Conversely, diversity is also reduced in communities growing at extreme depths where relatively few taxa can tolerate the very low light conditions present. Most diverse communities are found in shallow, protected localities and at depths where wave action is reduced. The type of substrate available is important in determining the species which can occupy a given site, but not necessarily important in determining overall community diversity. The most diverse floras noted during the study were found in epipelic communities. Many sandy substrates which show little macroscopic evidence of algal growth have very rich micro-algal communities. Diversity relationships in communities attached to solid substrates is complicated by interspecific interactions depending on the primary colonizers and subsequent community maturation. The available evidence indicates that the range of many oligotrophic species which originally occupied the entire upper Great Lakes has been severely restricted. Such populations are apparently adversely affected by very low levels of contamination, which suggests that they may be useful in early detection of adverse trends in the system. The recent introduction of a number of species not characteristic of oligotrophic systems, or indeed even of freshwater lakes, indicates continuing degradation of the upper Great Lakes.

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SECTION 1

INTRODUCTION

The composition, structure, and distribution of benthic primary producer communities in the upper Great Lakes have not been extensively investigated. Many of the communities present are not particularly conspicuous and, while they may be the prime food source for some invertebrates, their contribution to the total productivity of these very large, deep lakes is probably trivial. Most studies which have been carried out during the past several years have concentrated on particular species or communities which may create nuisance conditions or are strikingly indicative of ecological change. The nutritional requirements of *Cladophora* and its distribution have been extensively investigated due to the potential for nuisances caused by massive overgrowth of this organism in areas which have been significantly eutrophied. *Cladophora* overgrowths present a management problem in local regions of the upper lakes, but eutrophication has not proceeded to the point where they present a massive and pervasive problem as they do in Lakes Erie and Ontario. More recently, attention has focused on the invasion and dissemination of *Bangia* in the upper lakes. This organism was not noted in the upper lakes prior to 1970. It has subsequently become established and now forms a subdominant to dominant constituent of certain benthic assemblages in highly impacted areas of the upper lakes. Like *Cladophora*, this organism is viewed as a problem because it is conspicuous. Its preferred habitat is solid substrates within the wave zone. Its size, growth habit, and coloration render it readily visible and identifiable macroscopically. These conspicuous "problem" species, however, constitute only the highly visible end of a spectrum of highly complex and structured algal communities which occupy benthic substrates throughout the photic zone of the upper Great Lakes. Their abundant occurrence also, unfortunately, signals the terminal phase of a successional pattern caused by prolonged and extensive environmental modification.

The present study was largely motivated by consideration arising from the two points above. If effective management of the Great Lakes ecosystem is to be achieved, it is patently necessary to have a working knowledge of possible pathways of nutrients and toxicants within the system. In this context, benthic algal communities may play a larger role than would be expected on the basis of their productivity potential since they operate at the interface between the free water and the sediments which are the eventual repository of most nutrients and toxicants. It would also appear that succession within these communities might provide a particularly useful integrative assessment of biological change within the system. In this respect, benthic algal communities have some attributes which make them particularly desirable for this type of qualitative assessment.

The most obvious of these attributes is the simple fact that benthic algal communities are more or less permanently fixed in a specific area. This avoids a number of substantial difficulties associated with the analysis of phytoplankton associations. Within the present state of limnological research, it is virtually impossible to determine the history of conditions under which the assemblage represented by a particular phytoplankton sample actually developed. This is a particularly difficult problem in systems of the physical dimensions of the Laurentian Great Lakes, where strong gradients in pollutant concentrations are present and their dispersion is highly irregular.

Another characteristic of benthic communities is their diversity. It is quite unusual to find plankton collections with more than 100 taxa, and most plankton communities contain only a few tens of species. Particularly in the less perturbed regions of the Great Lakes, benthic algal communities often contain several hundreds of taxa. Further, these very species-rich communities generally have a very high evenness component (Stoermer 1975).

Although this aspect of benthic communities has not been thoroughly investigated in the Great Lakes, it appears that certain communities in the upper lakes have an unusual degree of stability. The most apparently stable benthic algal communities are those which exist at depths approximating the summer thermocline. To the best of our current knowledge, these communities exhibit very little seasonal succession, and many of the populations which inhabit them are known from Pleistocene pro-glacial lakes. It is thus possible that certain benthic algal communities presently existing in the Great Lakes are largely unchanged since the formation of these bodies of water. At the other extreme are the communities which inhabit highly perturbed areas. In most of these communities, seasonal succession is very intense with dominant populations being replaced several times in any given season. In many cases, the dominant populations in these communities are recent invaders of the system. Indeed the population succession in certain areas of the Great Lakes during the past 3 decades is on the scale usually associated with geological time. The extreme perturbations in certain local areas have led to the development of benthic algal communities which apparently have no analogues in natural environments. In other words, man's activities have created a unique set of environmental conditions and generated biological responses which have not previously been observed.

Although benthic algal communities would appear to offer, in many respects, an almost ideal tool for monitoring biotic change in large, complex systems such as the Laurentian Great Lakes, this potential has not been realized. There are several reasons for this.

Our present general model for practically oriented ecological studies assumes a pre-existing framework of "classical" taxonomic and distributional studies. Unfortunately, this assumption is not valid in the case of the benthic algae of the Great Lakes. There are no taxonomic keys which will cover more than a minor fraction of the taxa which occur in the system. This means that the average investigator is faced with an almost prohibitive task in making any meaningful analysis of the communities which are apt to be encountered in any particular region of study. There are many species

present in the Great Lakes flora which have only recently been reported from North America and, indeed, many species which are apparently new to science. Consistent and meaningful interpretation of many of the entities present in the Great Lakes flora will demand further basic systematic research.

The remarkable diversity of habitats occupied by benthic algal communities in the upper Great Lakes also makes community assessment difficult. During the course of the present investigation we sampled a number of community types which had not been previously considered. As one example, the sand substrates which predominate in southeastern Lake Michigan had previously been considered to be essentially "sterile" so far as development of any extensive algal communities. Appropriate sampling of such substrates, however, reveals the presence of a rich and diverse diatom flora. Many of the taxa present had previously been noted occasionally in nearshore plankton collections. Some of these species which had previously been considered rare are actually dominants in their primary habitat.

Communities developed on sand substrates show a rather striking depth zonation. As will be discussed more fully later, the diversity of benthic algal communities in the Great Lakes shows a consistent trend relative to depth. The most diverse communities are generally developed at depths greater than approximately 10 m. It appears that this is related to reduced wave action and the physical stability of the habitat. In general, communities in the surf zone are less diverse than those at greater depths. Maximum community diversity generally occurs at depths of 10-20 m. Although viable algal communities are present to depths of 30-40 m, diversity is again reduced, and the communities found at great depths are highly specialized and are generally composed of a few species specially adapted to such stenothermic and severely light-limited environments. As may well be appreciated, this depth-related community differentiation leads to significant difficulties in sampling. The most appropriate sampling methods demand the use of divers and non-conventional sampling gear to satisfactorily collect representative communities.

As may be appreciated, the characteristics of benthic algal communities in the upper Great Lakes and the lack of extensive previous study led to a number of difficulties in the design and implementation of this project. The extreme diversity of substrate and habitat types present in these large systems make complete survey sampling almost prohibitive. Since little previous information was available, much of the sampling undertaken was truly exploratory and many of the collections gathered are quite probably unique. We have attempted to accomplish two major objectives in the sampling work undertaken. The first is to gain as good a representation as possible of collections from the habitat types available. The second is to obtain comparable samples from the different lakes and different areas within the system which have been subjected to different levels of perturbation. A completely quantitative and objective definition of this latter quality is extremely difficult. Spot analyses of the physical conditions at the site at the time of collection are available for most of our collections. These analyses are, however, dubiously representative of the conditions which the communities may be subjected to over any appreciable course of time. This is, of course, generally true of nearshore areas of the Great Lakes where

brief and local differences in circulation patterns and dispersion of pollutants may grossly affect water quality. In the interest of completeness, we have also included biological analyses of a number of historical samples which may have limited ancillary data associated with them or the data, if present, may be of dubious precision. Although the inclusion of these samples is less than totally satisfactory, they do provide one of the few available time windows whereby the modification of the lakes' biota may be judged. We have also included a number of "samples of opportunity" in this analysis. These are collections added to the Great Lakes Research Division collection which were sampled in conjunction with other projects, but which provide information on habitats which are unusual or particularly difficult to collect.

In many cases, particularly for species which are minor components of older samples, the precise habitat of growth is difficult to define with certainty. Because diatom frustules are resistant to normal decay processes, their remains may be dispersed into other habitats. In the case of communities which exist in high energy environments, living cells may also be dispersed and remain viable for considerable periods of time. Some species appear to have evolved specific adaptations which allow them to regularly occupy the plankton. This is particularly true of certain species of *Campylodiscus*, *Entomoneis*, *Nitzschia*, *Plagiotropis*, and *Surirella*. All of these entities find their primary habitat in epipelic habitats, but are regularly noted in plankton collections. Particularly in shallow, severely eutrophied areas within the Great Lakes, such species may be important elements in plankton assemblages under certain conditions. Although they very rarely are numerical dominants in the flora, cells are relatively large and they may constitute an important component of phytoplankton assemblage biomass. Perhaps the most striking example of this is the distribution of *Surirella angusta* in Lake Ontario. Although this species is most commonly epipelic, it is an important element of plankton throughout Lake Ontario during the winter circulation of the lake. Although it may be argued that the terms are nearly synonymous (Hutchinson 1967) we have chosen to distinguish between tychoplanktonic and pseudoplanktonic. In this report we will apply the former term to species, such as the ones just described, which are regularly found in plankton collections and which appear to have the capability to occupy alternate habitats successfully. The term pseudoplanktonic will be reserved for cases where the incorporation of a particular taxon in the plankton is not apparently due to biological adaptation and where the entity is incapable of significant growth or reproduction in the plankton.

While this type of cross utilization of macrohabitats is, at least in many instances, relatively easy to define, the specific habitat requirements are much more difficult to deal with. Many of the communities treated in this study are structurally very complex. Perhaps the nearest terrestrial analogue is the situation found in tropical rain forests. Although the actual ranges of physical and chemical conditions which may occur within complex algal communities are poorly documented, it is obvious that there is significant within-community differentiation of growth habitat and occupancy among the species which compose a given community. It is thus perfectly plausible that species having both high and low light requirements could

occupy different physical strata in the same community. It is also quite possible that a species having a requirement for substantial organic loadings could find a suitable niche within a complex community growing in an otherwise "oligotrophic" environment. This type of specific microhabitat requirement may explain the apparent wide distribution of some species which are always rare in occurrence. Of particular interest to this study, it may serve to explain the apparent disjunct occurrence, in very low numbers, of species which are usually associated with nutrient or organically enriched environments in some complex algal communities in relatively pristine areas of the Great Lakes. This type of microhabitat differentiation is very difficult to deal with in a study of this type since real resolution of community physical structure demands application of advanced techniques and considerable expenditure of effort. Although this type of resolution is certainly desirable, and probably necessary to the fundamental solution of some problems in algal community ecology, it is beyond the scope of an exploratory investigation of the type undertaken here. It must be remembered, however, that the sampling methods employed in this project resulted in the collection of entire communities, and that the fine-scale differentiation of micro-habitats which may occur within the communities is submerged.

Some of the information generated during the course of this study has been independently published in the journal literature. A summary of diversity trends in communities in Lakes Michigan and Superior was compiled during the initial phases of the project (Stoermer 1975). The trends illustrated by these initial samples appear to be general. Information from this project has also been incorporated into an initial checklist of diatom taxa known to occur in the Great Lakes (Stoermer and Kreis 1978). This paper also reviews the literature pertaining to diatoms in the Great Lakes. The problems of accurate species identification when dealing with an extremely diverse and poorly known flora are frustrating and considerable basic taxonomic work remains to be done. We have documented new records of taxa in certain genera (Stoermer 1978, Stevenson and Stoermer 1978, Kreis and Stoermer 1979) but numerous new records remain to be published. The disposition of entities which are morphologically unique but not, at this point at least, identifiable with described taxa is more vexing. We have accumulated records of a large number of such apparently undescribed taxa during the course of the study. In many instances, they are very rare in occurrence and further collections would have to be made in order to document their range of variability. There are, however, a number of unknown taxa which are numerically important or even dominant elements of communities investigated. Description and formal publication of these entities will require further research.

SECTION 2

MATERIALS AND METHODS

A large variety of methods were used in the collection of samples reported here. Shallow water communities were collected by hand techniques appropriate to the substrate sampled. Whenever possible, a portion of the actual substrate was included in the sample to assure that all taxa characteristic of the site were included in the sample. In the case of massive and well-indurated substrates, it was necessary to scrape the material from the substrate. In many cases it proved desirable to utilize SCUBA gear even for shoreline collections, since it substantially improves access to communities which grow within the wave zone.

SCUBA was used extensively to sample communities occurring at depths beyond a few meters. Whenever possible, portions of the substrate were collected into containers and transported to the surface for further subsampling. The most convenient containers for solid substrates were found to be semi-rigid plastic boxes with "snap on" tops. They are relatively easy to handle with gloves, protect samples from damage, and are readily available at low price. Unconsolidated samples were collected by diver-operated short corers and the corers transported to the surface intact for subsampling. In general, SCUBA or surface supply diving were the preferred methods of collecting. They allow much greater selectivity and differentiation of micro-communities which would otherwise be neglected. One of the more interesting observations derived from diver sampling is the presence of occasional large "beds" of macroscopic green algae such as *Chara* *Nitella*, and *Dichotomosiphon*. These communities are very patchy in distribution, usually occurring in silty-sand substrates at depths from 10 to 20 m. Growth is uncommonly luxuriant, with *Nitella* plants commonly reaching 30 cm or more in height and *Dichotomosiphon* beds 15-20 cm. Very little is known about the extent or ecological importance of these communities. We have observed them in numerous localities, particularly in Lake Michigan. Masses of *Dichotomosiphon* have been reported to cause occasional problems at the Chicago water filtration plant by fouling trash screens at intakes. These instances usually occur after strong fall storms. Our sampling at these communities was limited, but they probably deserve further attention as they obviously furnish the preferred habitat of many invertebrates and fish.

Some of the samples reported were taken by conventional over-the-side ship sampling gear. Many of these collections were samples of opportunity, taken in conjunction with projects designed to gather other types of information. Solid substrates were collected by PONAR dredge and occasionally by rock dredge. Unconsolidated sediments were taken by a BENTHOS corer and the epipelic communities in the upper few millimeters of

the sediment were subsampled. These sampling methods are essentially "blind" and have a number of undesirable features. Samples taken by dredge are subject to some degree of disturbance and possible mechanical damage. The nature and degree of displacement of components of any particular community sampled is difficult to determine after sample recovery. This problem is less acute with core samples, which preserve fine features of sediment structure, and presumably biological community structure, with remarkable fidelity. With any of these techniques it is, of course, impossible to determine how characteristic the community recovered is of the environmental mosaic of the local area sampled. In the case of rock dredge samples, and to a lesser extent with other types of dredges, it is difficult to determine the precise depth and location of sampling.

Some of the most interesting samples from extreme depths analyzed during the course of this project were taken by the submersible STAR II during relatively brief operations in the Great Lakes a number of years ago. Only solid substrates were sampled, but these collections provide our only insight to the potentially interesting bryophyte associations which exist at depths of 30 m and greater in the Great Lakes.

In all instances samples were preserved immediately after collection. The most commonly employed fixative was formalin-alcohol, although glutaraldehyde and gluaraldehyde-paraformaldehyde were employed in some instances. These fixatives provide superior preservation of cytoplasmic structure.

After return to the laboratory, samples were split. One split was subsampled for observations on soft-bodied forms and the remainder permanently preserved as an archival sample. The second split was cleaned (Patrick and Reimer 1966) and subsamples of the cleaned material were prepared as strewn diatom mounts in HYRAX. Duplicate strewn diatom slides are preserved from each collection and the cleaned material is permanently preserved. Thus, four permanent samples are retained from each collection; preserved raw material, cleaned material, and duplicate prepared diatom mounts.

In an effort to gain some historical perspective on the trends in benthic algal distribution in the upper Great Lakes, we undertook considerable effort to locate and analyze historic samples from the region. The results of this effort were instructive but, to some degree, frustrating. Most of the material located consists of prepared diatom mounts. In most instances these are only a single slide which reached a permanent repository through exchange. In many cases the information regarding the site of collection and conditions are fragmentary and, in a number of instances which we investigated, the actual physical site of collection does not presently exist. This is particularly true of historic samples from the Chicago area where pre-1900 shoreline localities are now hundreds of meters inland due to bulkheading and filling in the lakefront. Even given these difficulties, these collections furnish a valuable record of biological change in the region. It is extremely unfortunate that more investigators do not follow simple good scientific practice by depositing permanent reference sets of their material. This is especially true of studies which involve

documentation of system response to specific environmental modifications. It is interesting to note that most of the collections recovered come from institutions in the eastern United States and Europe. The development of an adequate regional repository would certainly aid future investigators.

Population estimates from strewn diatom mounts were developed by identification and enumeration of specimens observed on multiple strip counts. Identification and counting was carried out at ca. 1200X using a microscope capable of providing at least 1.32 N.A. Identifications and numerical data were encoded and machine processed. Preliminary data reduction was accomplished through programs developed in our laboratory (FIDO) which calculate absolute and relative abundance estimates and associated error, diversity, and redundancy (ANALYZE). Reduced data are stored in sequential tape files. Summary information regarding number of occurrences and least and greatest abundance for all taxa in a given set (SUMMARY), or detailed information regarding a given taxon (FETCH), may be recovered from these files. Summary collection records are also available in the same format. Although this information is too extensive to reproduce here, interested parties may obtain it by requests directed to the author.

SECTION 3

RESULTS

The most economical and efficient method of conveying the information contained in a large exploratory data set of this type is something of a problem. We have attempted to tabulate the information in summary form. Even recognizing that strict categorization of the variable involved in a limited number of cases is not entirely appropriate, we feel that this is the most informative approach at the present time. Since we are dealing with many organisms which have not been subjected to experimental investigation, and indeed many which are relatively rarely reported, a more detailed approach is probably not justified. The summary we have adopted is given in Table 1 following.

In Table 1 the degree of environmental modification is categorized according to the following classes:

I. Refers to regions which are isolated from direct pollution sources and are the nearest modern analogues of the original state of the system. Examples would be isolated shoreline localities in Lake Superior and northern Lake Huron and the offshore islands and reefs of northern Lake Michigan. The extreme examples covered in this case are areas such as Superior Shoal in Lake Superior which is probably the most nearly pristine area sampled and which does have special floristic characteristics.

II. Refers to regions which are marginally impacted. This would include shoreline localities south of Saginaw Bay in Lake Huron and south of Ludington in Lake Michigan.

III. Refers to regions which are highly impacted. Examples would be Saginaw Bay in Lake Huron, southern Green Bay in Lake Michigan, and the lower Duluth embayment in Lake Superior. Also included are localities in the vicinity of major streams entering Lake Michigan and localities in the vicinity of direct discharges.

The observed abundance of a particular taxon within a region is designated according to the following code:

- D - Dominant populations comprising more than 20% to the total assemblage
- A - Abundant populations comprising 5-20% of the total assemblage
- C - Commonly observed populations comprising 1-5% of the total assemblage
- R - Rare populations comprising less than 1% of the total assemblage

V - Very rare populations few or single examples noted in the assemblage

The apparent habitat preference of a given taxon is specified according to the following code:

P - Epithytic
PP - Epiphytic species particularly associated with other algae
PV - Epiphytic species particularly associated with vascular plants
PB - Epiphytic species particularly associated with aquatic bryophytes
S - Epelic
SS - Epelic on sand or fine gravel
SF - Epelic on fine unconsolidated sediments, including organic sediments
E - Epipilhic
T - Tychoplanktonic, a somewhat special category indicating how regularly a particular taxon occupies planktonic assemblages

There is obviously a good deal of variation in the degree of specificity of a particular taxon to a particular substrate or habitat type. In some instances the requirement is quite specific. Examples of this would be the occurrence of Achnanthes hungarica on Lemna or the association of Navicula contenta fo. biceps with bryophytes. We should also caution that, whenever possible, we have attempted to designate the specific habitat of occurrence. Thus a species of Epithemia growing on depauperate Cladophora in crenulated limestone, as is common in northern Lake Huron, would be designated as "PP." If the specimens are so rare that the actual microhabitat was not observed, the more general habitat category is given. Much further research is needed to resolve the questions revolving around microhabitat specificity versus general ecological conditions.

As will be noted in the table, the specific growth habits of the taxa treated, if known, are indicated by a subscript according to the following code:

a - Attached organisms having particular morphological modifications of structures which allow them to remain sessile on a substrate
c - Colonial species which may be entwined within a complex community but which are not directly attached to a substrate
v - Vagile species which freely move through the matrix of complete communities or upon substrates

There are a number of usually sessile taxa which may become motile in response to particular conditions. In the following compilation, the usual growth habit observed is reported.

The apparent depth zonation preference exhibited by the populations treated in this study are designated by the following code:

S - Shallow water, less than 2 m depth, strongly affected by wave action
Sp - Same depth zone as above but designating localities which are protected from strong wave action

Please note that there are a number of serious errors in the table which gives codings for apparent habitat preference. This table is found at the top of page 10. It should read as follows:

P - Epiphytic
PP - Epiphytic species particularly associated with other algae
PV - Epiphytic species particularly associated with vascular plants
PB - Epiphytic species particularly associated with bryophytes
S - Epipelic
SS - Epipelic on sand or fine gravel
SF - Epipelic on fine unconsolidated sediments, including organic sediments
R - Epilithic
T - Tychoplanktonic, a somewhat special catagory indicating how regularly a particular taxon occupies planktonic asslemblages.

I - Intermediate depths, 2-10 m
D - Deep stations, 10-30 m
D+ - Used to designate taxa which were noted exclusively from very deep stations

The depth components contains factors affecting both the physiological mechanisms of cells, such as light quantity and quality, nutrient availability, and temperature and purely mechanical factors. It is clear that the latter factor is important, since our data indicate that many populations which are usually found in the intermediate depth range are also capable of developing in shallow water in protected areas. On the other hand, it is clear that a significant number of populations, particularly in areas which have not been severely polluted, are specifically adapted to occupy the zone of near constant temperature and nutrient conditions below the normal excursion of the summer thermocline in the upper Great Lakes. These populations are probably most sensitive to incipient eutrophication.

SECTION 4

DISCUSSION

On the basis of this study, it is clear that several factors must be accounted for in any meaningful discussion of distribution trends in benthic diatom assemblages in the upper Great Lakes. These include both natural characteristics of the environment and modification apparently brought about by human activities.

Reference to historic collections provides convincing evidence that certain particularly sensitive species, such as Didymosphenia geminata, have been excluded from significant portions of the system during the period of record. It is unfortunate that the history of this floristic change cannot be determined in greater detail so that we might gain some insight into critical levels of effect. The historic record is fragmentary, at best, so that this method of comparison is effectively closed.

Comparison of communities occupying physically similar habitats in different areas of the system, provides convincing evidence that anthropogenic effects result in a reduction in community diversity. Our results also indicate that both the richness and evenness components of calculated diversity indices are reduced. In other words, there appears to be an absolute reduction in the number of species which can occupy a given habitat at any particular time plus a disproportionate increase in the abundance of certain species tolerant of altered conditions. Reduction in diversity of this type is commonly observed in highly impacted areas and is well documented in the literature as attested to by the fact that diversity indices are commonly used as an index of biological "health" of a water body. It is particularly interesting that population exclusion and diversity reduction in Great Lakes benthic algal communities apparently begins at very low levels of perturbation and community diversity may be reduced even in situations which would be characterized as oligotrophic by most conventional rating criteria. Such sensitive biological measures may become increasingly useful as gross and obvious sources of pollution are brought under control, thus allowing more consideration and effort to be devoted to the real problem of maintenance and/or restoration of ecosystem function. It may reasonably be argued that such measures of ecosystem quality are particularly applicable to large, high quality and long residence time systems such as the Great Lakes. There is a tendency to ascribe the obvious and well documented symptoms of ecosystem disfunction, such as the collapse of major fisheries stocks, to equally obvious ecological insults such as the introduction of toxic materials, exotic competitor populations, or simple over-exploitation. Although the case is not as well documented, it is quite clear that equally large changes have taken place in primary producer communities which were

subjected to different types of stress. It is entirely plausible that effects at the primary producer level are propagated through the ecosystem to the eventual detriment of the terminal elements of the food chain and that effective management will demand actions to prevent modification of the segment of the ecosystem.

As indicated in the introduction, benthic algal communities would appear to be sensitive indicators of change. Although the results of the present study are indicative of the type of information which can be gained through this approach, it is apparent that further basic investigations are necessary in order to utilize it as a management tool. On the basis of our results, it may be confidently projected that the basic inventory of populations which occupy the Great Lakes is far from complete. It would seem reasonable that some effort be devoted to developing this type of very basic information. Further, this type of basic information needs to be systematized in some form that is readily available to investigators working on practical problems in environmental management. At the present time, accurate identification of benthic algal populations in the Great Lakes depends very strongly on access to the primary literature. Until reasonably comprehensive taxonomic treatments of the Great Lakes flora are developed, most investigators will find analysis of benthic algal communities in the lakes a very time consuming and substantially frustrating task.

Within the present state of the art, useful information regarding the state of particular areas within the system can be gained through study of benthic algal communities. Cautious and thoughtful application of the classical indicator species and diversity concepts can yield information that is difficult, if not impossible, to obtain through other approaches. Although these approaches have been criticized, the fact remains that major compositional or structural changes in a system are important events and any management system which is incapable of sensing such events is liable to serious errors. Most of the problems which arise from attempts to utilize such qualitative measures of ecosystem quality result from misapplication or overextension of the approach.

In the case of communities in the Great Lakes, application of the diversity approach is liable to misinterpretation unless physical factors of the environment are taken into account. Our results show that communities which develop in high wave energy environments are, as might be expected, considerably less diverse than communities which develop in either more protected localities or at depths sufficient to reduce wave energy. This tendency appears to be general, so that habitats exposed to extreme periodic turbulence have significantly less diverse floras regardless of other factors. Our results in fact suggest that the heavy growths of *Cladophora* which develop in highly eutrophic regions may allow the temporary development of more diverse associated micro-algal communities than are generally characteristic of exposed sites in less productive areas. This situation generally occurs in the fall, following the grand growth period of *Cladophora* and before strong fall storms result in the destruction of the complex community matrix. Significant reductions in community diversity are also observed in communities living at depths greater than ca. 20 m. Apparently, relatively few populations are able to adapt to the low light environment

present. The most curious situation occurs in bryophyte dominated communities which are found at depths of ca. 30 m in Lake Michigan. A large number of only a few species of diatoms are found associated with these communities and most abundant of these are the same species which are found in terrestrial moss communities. The most characteristic species is *Navicula contenta* fo. *biceps*. The factor or factors which could be common between aerophytic habitats and the conditions found at depth in Lake Michigan are difficult to imagine. It may be that these species are heterotrophic and require some specific material generated by the moss species they live upon, or the relationship may be a structural adaptation, since the diatoms apppear to have functional chloroplasts. Such specific associations may be more common than generally realized and, unless recognized, complicate the association of particular species with commonly measured environmental variables.

An example of this type of modification is found in the invasion of *Bangia* in Lake Michigan. This primarily marine species was first noted in Lake Erie in 1969 (Kishler and Taft 1970). We first noted it in Lake Michigan in 1972. The material occurred in beach seine collections from near the D. C. Cook nuclear power plant near Benton Harbor, Michigan. Due to the method whereby the material was obtained, the exact habitat of growth is unknown. Later observations along the Michigan coastline of Lake Michigan showed that *Bangia* populations were established at many localities where suitable substrates were present near the mouths of major streams entering the lake. During the early stages of *Bangia* invasion, it appeared to be limited to particular growth habitats and seasons. Established *Bangia* mats were usually found in the splash zone on rock or concrete substrates, and were only obvious during the early spring and late fall. It thus appeared that *Bangia* was replacing the *Ulothrix zonata* association which had characteristically dominated the habitat during the cold months of the year. The characteristics of the thallus and growth habitat of *Bangia* and *Ulothrix* are quite similar. Apparently because of the large, diffluent sheath characteristic of both taxa, neither supports an appreciable epiphyte flora. Since becoming established, however, *Bangia* has expanded its local range of occurrence, both temporally and spatially. During the past few years, luruxiant growths of *Bangia* have been noted in highly impacted areas throughout the year, except during periods of heavy ice scour. Furthermore, it appears to have adapted to a much wider range of physical habitats, and extensive beds are found on submerged rocks and other solid substrates. This species thus appears to be competing successfully with *Cladophora glomerata* in highly impacted areas. It is reasonable to project that this will have a significant effect on the composition and diversity of the total algal assemblage found in such areas. Unlike *Bangia*, *Cladophora* supports an extremely rich and diverse epiphyte flora. Although the extreme overgrowths of *C. glomerata* characteristic of eutrophied areas have caused this organism to be regarded as a nuisance, it should be pointed out that species of *Cladophora* are present throughout the Great Lakes system wherever suitable substrates and physical conditions exist. It usually forms a significant part of the "fabric" of benthic algal associations found on solid substrates. This is true even of associations in the most "oligotrophic" parts of the Great Lakes system, such as the epilithic communities found on Superior Shoal in Lake Superior. The replacement of *Cladphora* by *Bangia* in highly impacted

areas could thus signal a very extensive change in the entire algal association characteristic of such areas and a concomitant modification of the food base available to consumer organisms. Within the present state of knowledge, the eventual impact of such changes is almost impossible to fully project. It is clear, however, they are indicative of biological responses to ecosystem stress which propagate widely through the system. In the particular case of Bangia, this exotic population has now become a major element of epilithic communities in impacted areas throughout Lake Michigan and southern Lake Huron. We have not noted it in Lake Superior.

While microhabitat interactions make it difficult to infallibly characterize the relationship of particular populations to commonly measured water quality parameters, a number of trends of occurrence are obvious in our data. The clearest associations, as might be suspected, occur at the opposite ends of the spectrum of conditions found in the modern Great Lakes.

On the basis of our observations, a number of populations are exclusively associated with relatively high conservative ion and nutrient loadings. Most of these populations find their primary habitat in various benthic algal communities in brackish water situations. Included in this group are species such as Bacillaria paxillifer, Synedra fasciculata, and S. pulchella. Although occasionally reported from inland waters with high total dissolved solids, these species are clearly indicative of extreme conditions in the Great Lakes system. Although not noted in our collections, Terpsinoe musica Ehr., a species often abundant in brackish water and subtropical rivers, has recently been reported from Lake Michigan (Wujek and Welling 1979). The same authors also reported the occurrence of Biddulphia laevis Ehr. This species and others, such as Pleurosigma delicatulum, are also associated with high total dissolved solids, but usually in inland waters. The above species are often dominant populations in rivers in the western United States. Anomoeoneis costata is another species apparently tolerant of extreme osmotic stress. It is rare in the Great Lakes and restricted to grossly modified habitats, but is fairly widely distributed in eutrophic freshwater lakes. It reaches its maximum abundance in sodium carbonate lakes in endorheic regions and may be a dominant population of the restricted flora present in such lakes.

In a very real sense, these species represent the cutting edge of change in environmental quality in the upper Great Lakes. They are adapted only to the extreme of conditions generated by human activities.

The opposite end of the spectrum is represented by those species which, also in a very real sense, represent the trailing edge of floristic succession. Included in this category are entities such as Melosira arenaria which are best adapted to extremely oligotrophic and boreal conditions. In the fossil record of lakes formed during the Pleistocene they are considered indicators of proglacial lake phases (Stoermer 1977). Their continued existence in the upper Great Lakes apparently depends on sufficient light penetration to depths below the excursion of the summer thermocline which provides a niche for organisms adapted to low, and essentially invariant temperature conditions, in combination with very low levels of nutrients and other dissolved materials. It has been previously pointed out (Beeton and

Chandler 1966) that one of the unique characteristics of the Great Lakes fauna and flora is the extension of the latitudinal range of many primarily boreal species and the preservation of many "glacial relicts."

It is thus not particularly surprising that a disproportionate number of the species listed here are known primarily or exclusively from boreal localities and are often abundant in Pleistocene deposits. On the basis of our results, it is evident that the range of occurrence of many of these species is restricted in the modern Great Lakes. The best documented cases are large, conspicuous periphyton species such as Didymosphenia geminata. Due to the fact that this species is so distinctive that it would be consistently recognized, sufficient records are available to support the contention that it was originally present throughout the upper Great Lakes. At the present time,populations are restricted to Lake Superior. As will be noted from the compilation, a large number of species have similar patterns of modern distribution and we suspect that they were originally more widely distributed, although this cannot be proven on the basis of available records. Included in this group are several species of Achnanthes, particularly A. calcar, A. kryophila, A. levanderi, members of the A. oestrupi complex, and A. suchlandti. A number of species in the genus Diploneis are also known primarily from either boreal or fossil localities and are now restricted to the less modified parts of the upper Great Lakes. Included in this group are species such as D. boldtiana, D. domblittensis, D. finnica, and D. parma.

Observations on the limited number of historic samples which were available for study also support the contention that the range of many benthic diatoms has been restricted. Most of the samples which we have observed came from the Chicago region of Lake Michigan and many were collected in an attempt to study what were perceived as deleterious changes in the lake in the period from 1870 to 1890. Although not representative of pristine conditions, it will be noted that a large number of taxa were either much more abundant in the early samples than they are now, or present in those samples but not observed in modern Lake Michigan.

Firm interpretation of this pattern is limited by two factors. The first is our lack of knowledge of the growth habitat and distribution within the lake of many of these species. Perhaps the outstanding example of this is found in the distribution of several species of the genus Amphora in Lake Michigan. We originally reported the presence of several of these on the basis of rare occurrences in plankton collections (Stoermer and Yang 1971). Subsequent research has shown that they are, in fact, abundant in communities growing on the supposedly "sterile" sand substrates which are the primary available habitat in the southeastern part of the lake. Such substrates are rarely collected and the associated algal flora remains poorly known. It is possible that some of the more sensitive species which originally inhabitated the Chicago area still exist in isolated localities in northern Lake Michigan. The most probable localities are those in which the eutrophication of Lake Michigan is somewhat mitigated by exchange of water with Lake Huron (Schelske et al. 1976). The second factor is that the historic records are not sufficiently detailed to establish either the trend of exclusion of sensitive species or any correlation with levels of nutrients or other

factors. In the case of Didymosphenia geminata, it can be established that the species was abundant in the Chicago region in the 1870s (Briggs 1872) and still present in the 1880s (Thomas and Chase 1887). Populations were taken in deep water plankton tows in Grand Traverse Bay in the 1890's (Thompson 1896). Further verifiable records are lacking. The available water chemistry data is not sufficiently sensitive to allow the establishment of causal connections. Even at the present time, measurements of available nutrients in the range of interest are subject to appreciable uncertainties. Direct experimental evidence of the range of tolerance of these species is entirely lacking. So far as we have been able to determine, practically none of the species which are characteristic of undisturbed habitats in the upper Great Lakes have successfully been cultured in defined media.

On the basis of our observations, it appears that a considerable number of species which are restricted to Lake Superior in their modern distribution probably did not inhabit either Lake Michigan or Lake Huron in their unaltered states. Included in this group are several members of the genera Anomoeonesis, Eunotia, and Pinnularia which are characteristic of dystrophic lakes or other bodies of water with very low mineral solids content. Apparently due to natural drainage basin characteristics, the waters of the lower lakes did not furnish a suitable habitat. As will be noted from the compilation, some of these species are noted very rarely in collections from near river mouths in Lake Michigan. These specimens are probably derived from the drainages of dystrophic lakes or bogs and probably do not survive in Lake Michigan proper.

It should probably be pointed out that, with the exception of a few essentially monospecific genera, there is relatively little consistency in the distribution patterns of various species of most of the major genera found in the Great Lakes. Several genera have species which occupy opposite ends of the range of conditions which occur in the system. For instance, although Melosira arenaria is characteristic of extreme oligotrophic conditions, M. varians is usually found in very highly productive conditions and seems to be associated with relatively high organic loadings. As pointed out earlier, Anomoeoneis costata is largely restricted to areas where the waters have elevated dissolved solids content but A. follis is found only in waters with extremely low total dissolved solids. In these particular cases, it could be argued that this is the result of a highly artificial classification. In both of the cases cited above, there are significant morphological differences between the species compared and in both cases they might be placed in different genera under a more natural classification system. However, even in genera where such differences are not obvious, we still find extreme distributional differences among the members of a given genus. The most striking differences are found among some of the larger genera such as Cymbella Gomphonema Navicula, and Nitzschia, all of which have species which occur more or less abundantly in various segments of the range of conditions found in the upper Great Lakes.

In the genus Achnanthes, species such as A. delicatula, A. hauckiana, and A. hungarica are usually restricted to highly impacted areas. A number of common eurytopic species such as A. conspicua, A. lanceolata, and A. minutissima are common in areas which are significantly eutrophied.

Achnanthes affinis and A. minutissima are apparently tolerant of nutrient addition, but are also quite abundant in more oligotrophic regions. Together with species such as A. duthii, A. kryophila, A. oestrupi, and A. peragalli, they are characteristic of habitats which have received little disturbance. The most oligotrophic associations contain species such as A. calcar, A. flexella, A. gracillima, and A. subsaloides.

The distribution of members of the genus Amphipleura in the upper Great Lakes is somewhat unusual. Of the two species noted, A. arctica is substantially restricted to relatively unmodified parts of the system, but A. pellucida is very widely distributed. It is found in benthic associations throughout the region and may be present in significant quantities in plankton collections from disturbed areas. High populations of this taxon are characteristic of the Green Bay water mass and it is often found in abundance in the plankton of other more eutrophic regions of the lake.

Due to their habitat preference, the distribution of many of the species of Amphora occurring in the upper lakes has not been well documented. They are generally most abundant in epipelic communities, particularly in deep water. Species characteristic of disturbed areas include A. montana, A. normanii. A. veneta, and A. ovalis. The latter species appears to be more eurytopic than the others and its range extends into more oligotrophic habitats. Species such as A. calumetica, A. huronensis, and A. michiganensis are often relatively abundant on sand substrates in relatively little disturbed areas. In our collections, A. veneta var. capitata has been noted only in collections from areas receiving little disturbance. Previous records of this taxon are mostly from fossil localities.

Members of the genus Anomoeoneis are relatively rare components of benthic algal communities in the upper Great Lakes. As indicated earlier, A. costata is found only in highly disturbed habitats and is usually associated with very high total dissolved solids concentrations, indicative of disturbance in the Great Lakes. The other members of the genus reported are all characteristic of oligotrophic habitats and/or dystrophic habitats. Of these species, A. vitrea is by far the most common and widely distributed. The growth habit of this species is very unusual. It is usually free living and vagile, but may grow in large gelatinous masses and occasionally forms apical stalks, similar to Gomphonema. Specimens with this growth habit may be asymmetric, although similar to the "normal" form in other respects. The stalked form may be a cryptospecies, which has some interesting systematic implications, since the nomenclatural type is stalked.

Members of the genus Caloneis are generally minor components of the benthic communities investigated. The largest and most conspicuous member of the genus, C. amphisbaena, is restricted to eutrophied habitats. It is most abundant in epipelic communities in Saginaw Bay, Green Bay, and some of the salinified rivers entering Lake Michigan. The most widely distributed species is C. bacillum and its varieties, which is widely distributed throughout the upper lakes. Species such as C. limosa, C. nubicola, and C. ventricosa appear to be restricted to areas which have not been significantly disturbed.

Most members of the genus Cocconeis found in the upper Great Lakes are distributed throughout the system. Common species such as C. diminuta, C. placentula, and C. pediculus occur in very oligotrophic habitats but are more abundant in areas which are somewhat enriched. In the case of C. pediculus, particular abundance appears to be at least partially controlled by availability of suitable substrate. This species is a dominant epiphyte on Cladophora glomerata and its abundance is correlated with heavy growths of Cladophora. The sole exception to this type of general distribution pattern is found in C. placentula var. rouxii. This taxon is a dominant in collections from Superior Shoal, but essentially absent from other parts of the system.

An unusually large number of species of Cymbella occurs in the upper Great Lakes. Very few members of the genus are found in saline waters, and the Cymbella flora of local regions in the Great Lakes system which receive heavy conservative ion loadings is notably depauperate. Large populations of species such as C. affinis and C. prostrata are characteristic of eutrophied regions and these species, plus others such as C. cistula and C. mexicana, remain abundant in areas which receive relatively small nutrient loads. Relatively isolated regions in northern Lake Michigan and Lake Huron have very diverse assemblages of species of this genus. Species such as C. angustata, C. cesatii, C. cistula var. gibbosa, C. delicatula, C. latens, and C. proxima are relatively abundant and are important components of epilithic and epiphytic communities. These are also present, although usually less abundant, in benthic algal communities in the least disturbed areas of the upper lakes. Some apparently more sensitive species such as C. bremhii, C. laevis, and C. lunata are largely restricted to such areas. Perhaps the most curious pattern of distribution in the genus is that of C. triangulum. This large and coarse-walled species is fairly abundant in epipelic communities growing on sand substrates at depths of 10 m and below in Lake Superior. Cells are also commonly found in the plankton. The factors responsible for this highly atypical pattern of occurrence are not presently known.

We noted only two members of the genus Denticula in our collections. The most common is D. tenuis var. crassula which is widely distributed in areas which have not been extensively modified. It is rare or lacking in areas which have been appreciably eutrophied. The distribution of D. tenuis is much more restricted. It has only been found in the least disturbed habitats sampled.

Most members of the genus Diatoma occupy the opposite end of the spectrum of conditions. Diatoma tenue and its varieties and D. ehrenbergii are characteristic of regions receiving heavy nutrient and conservative ion loadings. High abundance of D. vulgare and its varieties is usually indicative of eutrophic conditions, although it appears less tolerant of salinification than D. tenue and is also found in less disturbed areas.

Most members of the genus Epithemia are epiphytes on aquatic vascular plants and some of the coarser species of filamentous algae. Most species also appear to be intolerant of high levels of physical turbulence and are usually most abundant in small ponds or other protected waters. As might be

expected, members of the genus are not generally abundant in communities occupying shoreline habitats in the upper Great Lakes. A fair diversity of species is found associated with algal communities at depth. Most of these species are usually found in oligotrophic areas and some of the species occurring in the Great Lakes, such as E. emarginata and E. smithii, were previously reported from fossil localities. The only species which is common in eutrophied areas is E. sorex, which is occasionally found in dense Cladophora mats.

Many of the species of the genus Fragilaria which are common in benthic communities can also occupy the plankton with greater or lesser degrees of success. In the Great Lakes high abundance of F. capucina in phytoplankton collections is usually associated with eutrophication. This species is somewhat more widely distributed in benthic communities. It and species such as F. brevistriata and F. construens are often important elements of Cladophora associations, although the latter species are also found in areas which have not been severely eutrophied. These species are most common in periphyton communities. Other species, such as F. pinnata and F. leptostauron, are usually epipelic. Of the two, F. pinnata is apparently more tolerant of eutrophication and more commonly found in plankton collections. Fragilaria leptostauron occurs most abundantly in oligotrophic habitats and its range is similar to that of F. vaucheriae var. capitellata, a primarily periphytic taxon. Species such as F. constricta fo. stricta, F. lapponica, and F. virescens are restricted to the most oligotrophic habitats sampled.

Members of the genus Frustulia are relatively rare in benthic communities occurring in the Great Lakes. Of the species present, F. vulgaris is the most widely distributed, followed by F. rhomboides var. amphipleuroides. Occasional specimens of these taxa were noted in collections from all of the lakes. Other members of the F. rhomboides complex are more restricted in distribution and more characteristic of highly oligotrophic habitats. Specimens of F. weinholdii were found only in historic collections from the Chicago region in Lake Michigan.

Gomphoneis herculeana was originally described from the Great Lakes and remains an important component of epiphytic and epilithic associations in relatively undisturbed regions of the system. Occasional specimens were found in disturbed areas, particularly during the winter months, but it is never an important element of assemblages in eutrophic areas. The range of G. eriense is much more restricted, and the few examples found in our study all came from Green Bay of Lake Michigan.

Members of the genus Gomphonema are abundant in epilithic and epiphytic communities in the upper Great Lakes. Some of the common eurytopic species are very widely distributed throughout the system. Species such as G. angustatum, G. intricatum var. pumila, and G. olivaceum are much more abundant in eutrophied areas, although occasional specimens are found in collections from undisturbed areas. In our collections G. parvulum, which is often cited as an indicator of degraded water quality, was quite abundant in areas which were not significantly disturbed. The range of certain species such as G. intricatum, G. manubrim, G. olivaceoides, and G. sphaerophorum was

more restricted and large populations of these species are characteristic of less disturbed habitats. Species such as G. helveticum, G. quadripunctatum, and G. subtile are characteristic of the most oligotrophic parts of the upper Great Lakes and populations were not found in disturbed areas.

Most members of the genus Gyrosigma are relatively large cells and most freshwater species are adapted to epipelic habitats. Like many other members of epipelic associations, they are commonly entrained into the plankton and occasional specimens are routinely noted in nearshore plankton collections from the upper lakes. Most of the species noted in our collections are more abundant in Lake Michigan than in either Lake Huron or Lake Superior. This is probably indicative of both a preference for more eutrophic conditions and the greater availability of suitable habitat in the Lake Michigan system.

Hannea arcus is characteristic of highly oligotrophic systems and is a dominant element of periphyton floras in the most oligotrophic large lakes of the world, such as Lake Baikal. It is present, but relatively rare, in the least disturbed regions of Lake Michigan and Lake Huron, but is abundant in some localities in Lake Superior.

In terms of the number of taxa present, Navicula is by far the largest genus represented in our collections. A number of the more abundant species are widely distributed throughout the system and apparently eurytopic. There are, however, a number of species with restricted distribution patterns which appear to be indicative of varying levels of eutrophication and disturbance. Species restricted to highly modified regions near major sources of nutrients and other pollutants include N. circumtexta, N. citrus, N. confervacea, N. integra, N. luzonensis, N. miniscula, N. pygmaea, N. quadripartita, and N. salinarum. All of these taxa are tolerant of highly eutrophic conditions and conservative ion contamination. A number of other species including N. costulata, N. cryptocephala var. intermedia, N. explanata, N. gregaria, N. latens, N. odiosa, N. protracta and its varieties, and N. viridula var. linearis are characteristic of disturbed, but less extreme conditions. A number of species are apparently restricted to areas which have received relatively little disturbance. Included in this group are taxa such as N. bacillum, N. bryophila, N. cocconeiformis, N. farta, N. fracta, N. jaernfeltii, N. ordinaria, N. pseudoscutiformisu and N. semenoides. A surprisingly large number of taxa are restricted to only the most oligotrophic habitats sampled. Included in this group are species such as N. aboensis, N. americana, N. contenta, N. globosa, N. gysingensis, N. levanderi, N. subtilissma, N. tecta, and N. tridentula.

Members of the genus Neidium are generally rare in benthic algal communities in the upper Great Lakes. None of the species present are particularly associated with highly disturbed areas. The most common and widely distributed species are N. dubium and N. iridis which are found in many localities throughout the system. A number of taxa including N. bisulcata, N. calvum, N. hitchcockii, and N. temperi are restricted to least disturbed localities. The pattern of occurrence of N. distincte-punctatum and N. kozlowi is unusual in that, in the Great Lakes, they are almost entirely restricted to deep-living epipelic communities.

The genus Nitzschia is often regarded as an indicator of pollution because of the extreme abundance of certain species in sites receiving high nutrient and organic loadings. Like most other genera, however, it contains species which have habitat preferences spanning the range of conditions found in the upper Great Lakes. Certain species such as N. apiculata, N. filiformis, and N. tryblionella and its varieties are largely restricted to highly disturbed regions. Others such as N. bulnheimiana, N. sublinearis, and N. capitellata occur most abundantly in regions which have been eutrophied. These regions also usually have greater abundance of some of the common eurytopic species which are widely distributed throughout the lakes. A number of species are more characteristic of oligotrophic regions. Included in this group are species such as N. angustata var. acuta, N. denticula, and N. sinuata var. tabellaria.

Although there are a relatively large number of species present, members of the genus Pinnularia usually constitute a very minor component of benthic algal assemblages in the upper Great Lakes. As discussed earlier, many of the species in the genus are most abundant in highly oligotrophic environments. Many of these populations are restricted entirely to Lake Superior. None of the species in this genus appear to be particularly associated with eutrophic conditions, although some, such as P. brebissonii and P. viridis, are widely distributed and apparently tolerant of a considerable range of conditions.

Members of the genus Rhopalodia are similar in growth habitat to members of the genus Epithemia. Although suitable habitats are not widely available, Rhopalodia gibba is found in greater or lesser abundance throughout the upper Great Lakes. The next most abundant species, R. gibberula, is considerably less widely distributed and appears to be restricted to areas which have elevated levels of dissolved solids. The opposite tendency is found in R. parallela, which was only found in collections from highly oligotrophic habitats.

The ecological affinities and distribution patterns of members of the genus Stauroneis are quite similar to those of members of the genus Pinnularia. Certain species such as S. acutiscula and S. phoenicenteron are widely distributed, although rarely very abundant throughout the system. The majority appear to be restricted to regions which have not been significantly disturbed. One of the most characteristic species is S. dilatata, which has not been widely reported from North America except in the Great Lakes (Stoermer 1978).

The genus Stenopterobia is largely restricted to ultraoligotrophic or dystrophic environments. The only species noted in our collections, S. intermedia, was only found in collections from Lake Superior.

Surirella is a relatively large and complex genus, containing many apparently endemic genera. Many of the species in the genus have very large cells and the majority are adapted to epipelic habitats. Many of them are found, usually in low abundance, in plankton collections. They can apparently survive extended entrainment in the plankton and may constitute a significant portion of the biovolume of phytoplankton assemblages because of

the large size of individual cells. The genus contains a large number of morphological types, and these are, to some extent, characteristic of certain ecological affinities. In the Great Lakes, *S. delicatissima* is representative of a number of species which have some morphological similarities to members of the genus *Stenopterobia*. Like *Stenopterobia* they tend to be restricted to very oligotrophic environments. In our collections *S. delicatissima* was noted only in collections from undisturbed habitats in Lake Huron and Lake Superior. The opposite extreme is represented by species such as *S. ovalis* and the *S. ovata* complex. These species are tolerant of eutrophic conditions and are most abundant in waters with elevated levels of total dissolved solids. These species, together with *S. angusta* which is somewhat more widely distributed, are characteristic of epipelic communities in Saginaw Bay of Lake Huron and lower Green Bay in Lake Michigan. They are also occasionally abundant in plankton collections from these areas, and occasional specimens are found in nearshore plankton collections taken in the vicinity of larger rivers in Lake Michigan. Most other species in the genus are relatively rare and their distribution patterns are not completely known.

Members of the genus *Synedra* are important components of periphyton communities in the upper Great Lakes. Many of the species present are widely distributed and apparently eurytopic, but some have well defined occurrence patterns. As discussed earlier, *S. fasciculata* and *S. pulchella* are restricted to areas receiving gross conservative ion contamination. Species such as *S. tenera*, *S. ulna* var. *amphirhynchus*, *S. ulna* var. *oxyrhynchus*, and *S. vaucheriae* var. *capitellata* are characteristic of rich periphyton associations found in relatively undisturbed areas. They are apparently tolerant of moderate nutrient loadings, but are displaced from communities in areas which receive heavy loadings. This genus also contains a large number of morphological entities which cannot be identified with known species. Most of these are most common in oligotrophic habitats.

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TABLE 1. SUMMARY OF BENTHIC DIATOM POPULATION DISTRIBUTION IN THE UPPER GREAT LAKES

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
ACHNANTHES													
Achnanthes affinis Grun.	D	A	R	A	A	R	A	A	R	R, SS	P	Sp-D	Widely Distributed
Achnanthes amoena Hust.	R	O	O	O	O	O	O	O	O	R	-	D	Rare, Boreal
Achnanthes atacamae Hust.	-	R	-	-	R	-	-	-	-	SSa	Ra	I	
Achnanthes biasolettiana (Kütz) Grun.	C	R	V	C	R	V	C	C	-	SSa	Ra	Sp-D	Oligotrophic
Achnanthes bioreti Germain	R	R	V	R	R	V	R	R	-	SSa	Ra-PPa	Sp-I	Eurytopic
Achnanthes calcar Cl.	R	O	O	R	R	O	C	R	O	SSa	Ra	Sp-I	Oligotrophic
Achnanthes clevei Grun.	C	C	R	C	C	C	C	C	C	SSa	Ra, T	I-D	Eurytopic
Achnanthes clevei var. rostrata Hust.	C	C	R	C	C	C	R	R	V	SSa	Ra, T	I-D	Occasionally on plankton
Achnanthes coarctata (Bréb.) Grun.	O	O	O	O	O	O	V	O	O	Ra	-	Sp	Aerophytic, Allochthonous
Achnanthes conspicua A. Mayer	R	C	C	R	R	C	V	V	R	SSa	Ra	Sp-I	Eutrophic
Achnanthes conspicua var. brevistriata Hust.	O	V	O	O	O	O	O	O	O	SSa	-	I	
Achnanthes deflexa Reim.	C	R	V	C	C	-	C	C	-	Ra, SSa	PPa	Sp-D	Distribution poorly known
Achnanthes delicatula (Kütz.)Grun.	O	O	V	O	O	O	O	O	O	SSa	-	I	Halophilic (?)
Achnanthes detha Hohn and Hellern.	V	R	V	O	O	O	O	O	O	S	-	I	Distribution poorly known
Achnanthes didyma Hust.	O	O	O	V	O	O	R	R	O	SSa	-	Sp	Rare, Boreal
Achnanthes dispar Cl.	O	V	R	V	O	O	O	O	O	SSa	-	I	Boreal, Halophilic (?)
Achnanthes duthii Sreen.	R	O	O	C	R	O	C	C	O	PP, R	-	Sp-I	Distribution poorly known
Achnanthes exigua Grun.	R	R	C	R	R	C	V	R	R	Ra, SSa	Pb	Sp-I	Widely distributed
Achnanthes exigua var. constricta Torka	R	R	C	R	R	R	V	V	V	Ra, SSa	Pb	Sp-I	
Achnanthes exigua var. *heterovalva* Krasske	R	R	C	R	R	R	V	V	V	Ra, SSa	Pb	Sp-I	Eurytopic
Achnanthes exigua var. *heterovalva* fo. *semiaperta* Guer.	R	O	O	R	O	O	R	R	O	SSa	Ra	Sp-I	Distribution poorly known
Achnanthes flexella (Kütz.) Brun	C	R	V	C	R	V	D	A	V	SSa	Ra	Sp-I	Boreal, Oligotrophic

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	Lake Michigan II	Lake Michigan III	Lake Huron I	Lake Huron II	Lake Huron III	Lake Superior I	Lake Superior II	Lake Superior III	Primary habitats	Secondary habitats	Depth range	Notes
Achnanthes gracillima Hust.	0	0	0	0	0	0	V	0	0	?	T	?	Distribution poorly known
Achnanthes hauckiana Grun.	0	V	R	0	0	0	0	0	0	SSa	T	Sp-I	Halophilic (?)
Achnanthes hauckiana var. *rostrata* Schulz	0	V	R	0	0	0	0	0	0	SSa	T	Sp-I	More abundant than nominate variety
Achnanthes hungarica (Grun.) Grun.	0	0	R	0	0	V	0	0	0	PV	T	Sp	Probably allochthonous
Achnanthes kryophila Peters.	0	0	0	0	0	0	R	V	0	SSa	Ra	Sp-I	Boreal, oligotrophic
Achnanthes kryophila var. *africana* Choln.	0	0	0	0	0	0	C	R	0	SSa	Ra	Sp-I	Distribution poorly known
Achnanthes lanceolata (Bréb.) Grun.	R	R	C	R	R	R	R	R	R	SSa	Ra	Sp-D	Eurytopic, widely distributed
Achnanthes lanceolata var. *abbreviata* Reim.	R	R	C	R	R	R	V	0	0	SSa	Ra	Sp-I	Distribution poorly known
Achnanthes lanceolata var. *apiculata* Patr.	0	0	R	0	0	0	0	0	0	SSa	Ra	Sp	
Achnanthes lanceolata var. *dubia* Grun.	R	R	C	R	R	C	R	R	R	SSa	Ra	Sp-I	Eurytopic
Achnanthes lanceolata var. *haynaldii* (Schaarsch.) Cl.	0	0	V	0	0	0	V	0	0	SSa	-	Sp	Distribution poorly known
Achnanthes lanceolata var. *omissa* Reim.	R	R	C	R	R	R	V	V	R	SSa	Ra	Sp-I	
Achnanthes lanceolatoides Sov.	0	V	0	0	0	0	0	0	0	SSa	-	I	Very rare, apparently oligotrophic
Achnanthes lapponica (Hust.) Hust.	0	V	0	0	0	0	0	0	0	T	-	-	Known only from historic samples
Achnanthes laterostrata Hust.	V	0	0	R	V	0	R	R	0	SSa	Ra	Sp-I	Boreal
Achnanthes lauenburgiana Hust.	V	R	R	0	V	V	0	0	0	SSa	T	I	Distribution poorly known
Achnanthes lemmermanni Hust.	0	R	R	0	0	0	0	0	0	?	-	I	Perhaps allochthonous
Achnanthes levanderi Hust.	V	0	0	R	0	0	C	R	-	SSa	Ra	Sp-I	Boreal, oligotrophic
Achnanthes linearis (W. Sm.) Grun.	C	C	R	R	R	R	R	R	R	SSa	Ra	I-D	More abundant in historic samples
Achnanthes linearis fo. *curta* H.L. Sm.	R	R	R	0	0	0	0	0	0	SSa	-	I	
Achnanthes marginulata Grun.	R	0	0	R	R	0	R	R	0	SSa	Ra	Sp-I	Oligotrophic, Boreal
Achnanthes microcephala (Kütz.) Grun.	C	R	R	C	R	R	C	C	-	PPa	SSa	Sp-I	
Achnanthes minutissima Kütz.	D	C	R	D	C	R	D	C	R	PPa	Ra	Sp-I	Widely distributed

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Achnanthes minutissima var. *cryptocephala* Grun.	R	R	V	C	R	V	A	C	R	PPa	Ra	Sp-I	
Achnanthes oestrupi (A.Cl.) Hust.	C	V	V	R	V	0	C	R	R	SSa	Ra	D-Sp	Boreal
Achnanthes oestrupi var. *lanceolata* Hust.	R	0	0	R	0	0	R	R	0	SSa	Ra	D-Sp	
Achnanthes peragalli Brun and Hérib.	R	V	0	R	V	0	R	R	0	SSa	Ra	D-Sp	Boreal
Achnanthes pinnata Hust.	R	C	A	0	V	R	0	0	0	SSa	Ra	I-D	Distribution poorly known, apparently eutrophic
Achnanthes ploenensis Hust.	0	V	0	0	0	0	0	0	0	SSa	-	I	
Achnanthes procera Hust.	V	0	0	0	0	0	R	R	0	SSa	Ra	Sp-I	
Achnanthes sublaevis Hust.	V	0	0	V	0	0	R	R	0	SSa	Ra	Sp-I	Boreal
Achnanthes subsaloides Hust.	0	0	0	0	0	0	R	R	0	SSa	Ra	Sp-I	
Achnanthes suchlandti Hust.	V	0	0	0	0	0	R	R	0	SSa	Ra	Sp-I	
AMPHIPLEURA													
Amphipleura arctica Patr. and Freese	V	R	R	0	V	0	0	0	0	SSv	T	I-D	Most abundant in older samples
Amphipleura pellucida (Kütz.) Kütz.	C	C	A	C	C	A	R	R	C	SSv	T	Sp-I	Widely distributed
AMPHORA													
Amphora bullatoides Hohn and Hellerm.	0	R	R	0	0	0	0	0	0	SSa	Ra	I-D	Distribution poorly known
Amphora calumetica (Thomas) M. Perag.	C	C	R	C	C	R	V	0	0	SSa	Ra	I-D	Apparent endemic
Amphora cruciferoides Stoerm. and Yang	V	R	R	0	0	V	0	0	0	SSa	Ra	D-I	Recently described, apparent endemic
Amphora fonticola Maill.	V	V	V	V	0	0	0	0	0	SSa	Ra	D-I	
Amphora hemicycla Stoerm. and Yang	V	R	R	0	V	V	0	0	0	SSa	Ra	D-I	Recently described
Amphora huronensis Stoerm. and Yang	V	V	0	V	V	0	0	0	0	SSa	Ra	D-I	Recently described
Amphora michiganensis Stoerm. and Yang	A	C	R	R	R	V	V	V	0	SSa	Ra	D-I	Recently described, also in small lakes of the region
Amphora montana Krasske	0	0	R	0	0	0	0	0	0	Ra	PP	Sp	Widely distributed, eutrophic
Amphora neglecta Stoerm. and Yang	V	R	R	V	R	R	0	0	0	SSa	Ra	D-I	Recently described
Amphora normanii Rabh.	0	0	V	0	0	0	0	0	0	Ra		I	Perhaps allochthonous

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	Lake Michigan II	Lake Michigan III	Lake Huron I	Lake Huron II	Lake Huron III	Lake Superior I	Lake Superior II	Lake Superior III	Primary habitats	Secondary habitats	Depth range	Notes
Amphora ovalis (Kütz.) Kütz.	C	D	D	C	C	C	R	R	C	SSa	Ra	I-D	Widely distributed
Amphora ovalis var. *constricta* Skv.	R	O	O	R	O	O	R	O	O	SSa	Ra	I-D	Distribution poorly known
Amphora ovalis var. *gracilis* (Ehr.) V.H.	O	R	O	O	O	O	V	O	O	SSa	Ra	I-D	
Amphora ovalis var. *libyca* (Ehr.) Cl.	R	R	R	R	R	R	R	R	R	SSa	Ra	I-D	Widely distributed
Amphora ovalis var. *pediculus* (Kütz.) V.H.	C	D	A	C	A	C	R	R	C	SSa	Ra	I-D	Widely distributed
Amphora perpusilla (Grun.) Grun.	C	A	A	C	A	A	R	R	R	SSa	Ra	I-D	
Amphora rotunda Skv.	O	O	R	O	O	O	O	O	O	?	?	?	Distribution poorly known
Amphora sibirica Skv. and Meyer	R	R	R	O	O	O	O	O	O	SSa	Ra	I-D	Most common in historic samples
Amphora subcostulata Stoerm. and Yang	R	R	R	R	R	O	V	O	O	SSa	Ra	I-D	Recently described
Amphora veneta Kütz.	R	C	R	O	O	O	O	O	O	SSa	Ra	S	Eutrophic
Amphora veneta var. *capitata* Haworth	R	R	V	V	V	O	R	R	V	SSa	Ra	Sp-I	Most reports from fossil localities
ANOMOEONEIS													
Anomoeoneis costata (Kütz.) Hust.	O	V	V	O	O	O	O	O	O	SF	SS	Sp	Halophilic, perhaps allochthonous
Anomoeoneis follis (Ehr.) Cl.	O	O	O	V	O	O	V	O	O	SF	-		Dystrophic
Anomoeoneis serians var. *brachysira* (Bréb.) Hust.	O	O	O	O	O	O	V	V	O	SF	SS	SP	Oligotrophic-dystrophic
Anomoeoneis styriaca (Grun.) Hust	V	O	O	V	O	O	V	O	O	SF	SS	SP-I	
Anomoeoneis vitrea (Grun.) Ross	R	V	V	C	R	O	A	C	V	SF	SS	Sp	
Anomoeoneis zellensis (Grun.) Cl.	V	O	O	O	O	O	O	O	O	SF	-	I	
BACILLARIA													
Bacillaria paxillifer (O. F. Müll.) Hendy	O	V	V	O	O	V	O	O	O	SSv	-	Sp	Halophilic
CALONEIS													
Caloneis alpestris (Grun.) Cl.	C	R	V	C	V	O	R	R	O	SF	SS	Sp-I	
Caloneis amphisbaena (Bory) Cl.	O	O	R	O	O	R	O	O	O	SF	SS	Sp-I	Halophilic

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	Lake Michigan II	Lake Michigan III	Lake Huron I	Lake Huron II	Lake Huron III	Lake Superior I	Lake Superior II	Lake Superior III	Primary habitats	Secondary habitats	Depth range	Notes
Caloneis bacillaris var. *thermalis* (Grun.) A.Cl.	R	V	V	R	V	V	V	V	0	SF	SS	Sp-I	
Caloneis bacillum (Grun.) Cl.	R	R	V	R	R	V	R	R	V	SF	SS	Sp-I	Widely distributed
Caloneis bacillum var. *lancettula* (Schulz) Hust.	R	R	V	R	R	V	R	V	V	SF	SS	Sp-I	
Caloneis clevei (Lagerst.) Cl.	0	V	0	0	0	0	V	0	0	SF	SS	Sp-I	Distribution poorly known
Caloneis lewisii Patr.	V	V	0	0	0	0	V	0	0	SF	SS	Sp	Generally rare
Caloneis limosa (Kütz.) Patr.	V	V	0	0	0	0	V	V	0	SF	SS	Sp-I	
Caloneis nubicola (Grun.) Cl.	0	0	0	0	0	0	V	0	0	SF	SS	Sp-I	
Caloneis ventricosa (Ehr.) Meist.	V	0	0	V	0	0	V	0	0	SF	SS	Sp-I	
Caloneis ventricosa var. *minuta* (Grun.) Patr.	0	V	0	0	0	0	0	0	0	SF	SS	Sp-I	
Caloneis ventricosa var. *truncatula* (Grun.) Meist.	R	V	0	R	V	0	R	R	0	SF	SS	Sp-I	
CAMPYLODISCUS													
Campylodiscus noricus var. *hibernica* (Ehr.) Grun.	V	0	0	V	0	0	0	0	0	SF	SS	I-D	
CAPARTOGRAMMA													
Capartogramma crucicula (Grun.) Ross	0	0	V	0	0	V	0	0	0	SS	SF	S-I	Halophilic
COCCONEIS													
Cocconeis diminuta Pant.	C	A	C	C	C	C	C	C	R	Ra	SSa	D-I	
Cocconeis disculus (Schum.) Cl.	R	R	R	R	R	R	R	R	R	Ra	SSa	I-D	
Cocconeis pediculus Ehr.	A	A	D	A	A	D	R	R	C	PP	-	S-I	Common on Cladophora sp.
Cocconeis placentula Ehr.	R	R	R	R	R	R	R	R	R	Ra	PP	S-D	
Cocconeis placentula var. *euglypta* (Ehr.) Grun.	C	C	D	C	C	D	R	C	C	Ra	SSa	S-D	
Cocconeis placentula var. *lineata* (Ehr.) V. H.	C	C	R	C	C	R	D	C	C	Ra	SSa	S-D	
Cocconeis placentula var. *rouxii* (Hérib. and Brun) Cl.	0	0	0	0	0	0	D	0	0	Ra	-	I	Oligotrophic

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
CYMATOPLEURA													
Cymatopleura cochlea J. Brun	V	R	R	O	V	R	O	O	O	SF	T	I	More common in historic samples
Cymatopleura elliptica (Bréb. and Godey) W. Sm.	V	R	R	O	V	R	O	O	O	SF	T	I	
Cymatopleura solea (Bréb. and Godey) W. Sm.	R	R	R	V	R	R	V	V	V	SF	T	I	
Cymatopleura solea var. *apiculata* (W. Sm.) Ralfs	V	R	R	V	R	R	O	O	V	SF	T	I	
Cymatopleura solea var. *clavata* O. Müll.	O	V	O	O	O	O	O	O	O	SF	T	I	
Cymatopleura solea var. *regula* (Ehr.) Grun.	O	V	O	O	O	O	O	O	O	SF	T	I	Only found in historic samples
CYMBELLA													
Cymbella acutiuscula Cl.	O	O	V	O	O	O	O	O	O	SS?	-	I	Probably allochthonous
Cymbella aequalis W. Sm.	V	O	O	O	O	O	O	O	O	SS?	?	?	
Cymbella affinis Kütz.	R	R	R	R	R	R	R	R	R	PPa	Ra	I	Eurytopic
Cymbella amphicephala Näg.	V	O	O	V	O	O	V	O	O	SS	R	I	
Cymbella amphicephala var. *subundulata* Cl.	V	O	O	O	O	O	O	O	O	SS	R	I	
Cymbella angustata (W. Sm.) Cl.	V	O	O	V	O	O	R	O	O	SS	R	I	Only old L. Michigan samples
Cymbella aspera (Ehr.) H. Perag.	V	V	O	V	O	O	R	O	O	SF	P	Sp-I	
Cymbella aspera var. *minor* (V.H.) Cl.	O	O	O	O	O	O	V	O	O	SF	-	Sp	
Cymbella brehmii Hust.	O	O	O	O	O	O	C	O	O	Ra	-	I-D	
Cymbella cesatii (Rabh.) Grun.	R	R	V	R	R	O	A	C	R	SF	SG	Sp-I	
Cymbella cistula (Ehr.) Kirchn.	A	R	R	A	R	R	A	C	R	Ra	PPa	S-I	Widely distributed
Cymbella cistula var. *gibbosa* Brun	C	R	O	C	R	O	C	C	O	Ra	PPa	S-I	Oligotrophic
Cymbella cistula var. *truncata* J. Brun	R	O	O	R	O	O	C	O	O	Ra	PPa	S-I	
Cymbella cuspidata Kütz.	R	V	V	R	V	O	R	R	O	Ra	PPa	S-I	
Cymbella cuspidata var. *schulzii* A. Cl.	V	O	O	O	O	O	R	O	O	SF	-	Sp-I	
Cymbella delicatula Kütz.	C	R	V	C	R	V	A	C	V	S	-	Sp-I	Boreal, oligotrophic

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Cymbella hustedtii Krasske	A	C	R	A	C	R	C	R	O	S	R	I-D	
Cymbella hybrida Grun.	R	R	O	R	R	V	R	R	O	S	-	I-D	
Cymbella inaequalis (Ehr.) Rabh.	V	O	O	O	O	O	O	O	O	S	-	I	
Cymbella incerta (Grun.) Cl.	V	O	O	O	O	O	O	O	O	S	-	I-D	
Cymbella laevis Näg.	R	O	O	C	R	O	A	C	O	S	-	Sp-I	
Cymbella lanceolata (Ag.) Ag.	R	O	O	R	O	O	R	O	O	PVa	Ra	Sp-I	
Cymbella lata Grun.	V	V	O	O	O	O	O	O	O	Ra	PPa	I	
Cymbella latens Krasske	C	C	R	C	C	V	A	C	R	S	R	Sp-I	
Cymbella leptoceros (Ehr.) Kütz.	R	O	O	R	O	O	R	O	O	Ra	PPa	I	
Cymbella leptoceros var. *rostrata* Hust.	R	V	O	R	O	O	R	V	V	SS	R	Sp-I	
Cymbella lunata W. Sm.	O	O	O	O	O	O	R	O	O	SS	R	Sp	
Cymbella mexicana (Ehr.) Cl.	R	V	V	R	V	V	R	V	V	Ra	PPa	I	
Cymbella microcephala Grun.	A	C	C	A	C	C	C	C	C	S	P, R	Sp-I	Widely distributed
Cymbella minuta Hilse	R	R	R	R	R	R	V	R	R	PP	S	Sp-I	Widely distributed
Cymbella minuta var. *pseudogracilis* (Choln.) Reim.	R	V	O	R	O	O	R	V	O	PP	S	Sp-I	
Cymbella minuta var. *silesiaca* (Bleisch) Reim	O	O	O	O	O	O	V	O	O	PP	S	Sp	
Cymbella muelleri Hust.	R	O	O	R	V	O	R	V	O	S	R	Sp-I	More common in historic samples
Cymbella muelleri fo. *ventricosa* (Temp. and Perag.) Reim.	O	O	O	O	O	O	R	O	O	R	-	I	
Cymbella naviculiformis Auersw.	R	O	O	R	O	O	R	O	O	S	R	Sp-I	More common in historic samples
Cymbella norvegica Grun.	R	R	O	R	O	O	O	O	O	S	-	Sp-I	
Cymbella obtusiuscula Kütz.	R	R	O	R	V	O	R	V	O	S	R	Sp-I	
Cymbella parva (W. Sm.) Cl.	V	V	O	O	V	O	V	V	O	S	R	Sp-I	
Cymbella parvula Krasske	V	V	V	V	V	O	V	V	O	S	R	S-I	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Cymbella prostrata (Berk.) Cl.	R	C	C	R	R	C	V	R	C	PP	S	S-I	Common in Cladophora communities
Cymbella prostrata var. *auerswaldii* (Rabh.) Reim.	R	C	R	R	R	R	R	R	R	PP	S	S-I	
Cymbella proxima Reim.	R	V	O	R	V	O	R	V	O	PP	S	I-S	
Cymbella sinuata Greg.	C	R	V	C	R	V	V	R	V	S	R	Sp-D	
Cymbella sinuata var. *antiqua* (Grun.) Cl.	V	O	O	V	O	O	C	R	O	S	R	Sp-D	
Cymbella sinuata fo. *ovata* (Hust.) Hust.	V	O	O	V	O	O	V	O	O	S	-	Sp-D	
Cymbella subaequalis Grun.	O	O	O	O	O	O	V	O	O	S	-	Sp	
Cymbella subventricosa Choln.	V	O	O	R	O	O	A	R	O	S	PP	Sp	
Cymbella triangulum (Ehr.) Cl.	R	V	O	R	R	O	R	R	V	S	T	I-D	Often found in L. Superior plankton.
Cymbella tumida (Bréb.) V.H.	V	V	V	O	V	V	V	V	V	PP	R		
Cymbella tumidula Grun.	O	O	V	O	O	O	O	O	O	R	-	S	
CYMBELLONITZSCHIA													
Cymbellonitzschia diluviana Hust.	O	O	V	O	O	O	V	O	O	S	-	S	
DENTICULA													
Denticula tenuis Kütz.	O	O	O	O	O	O	C	O	O	R	S	I-D	
Denticula tenuis var. *crassula* (Näg.) W. and G.S. West	A	C	V	A	C	V	D	A	R	S	R	I-D	
DIATOMA													
Diatoma anceps (Ehr.) Kirchn.	O	O	O	O	O	O	R	O	O	R	A	Sp	
Diatoma anceps var. *linearis* M. Perag.	O	V	O	O	O	O	O	O	O	R	-	I	Probably allochthonous
Diatoma ehrenbergii Kütz.	V	R	C	O	O	R	O	O	O	R	S	S-I	Halophilic
Diatoma hiemale (Roth) Heib.	O	O	O	O	O	O	V	O	O	R	S	Sp	
Diatoma hiemale var. *mesodon* (Ehr.) Grun.	V	O	O	O	O	O	V	O	O	R	S	Sp	
Diatoma tenue Ag.	R	C	C	V	R	R	V	V	C	R	T	Sp-I	Common in plankton

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	Lake Michigan II	Lake Michigan III	Lake Huron I	Lake Huron II	Lake Huron III	Lake Superior I	Lake Superior II	Lake Superior III	Primary habitats	Secondary habitats	Depth range	Notes
Diatoma vulgare Bory	R	R	C	R	R	C	R	R	C	R	PP	S	Common in Cladophora communities
Diatoma vulgare var. *breve* Grun.	O	R	R	O	O	O	O	O	O	R	PP	S	
Diatoma vulgare var. *grande* (W. Sm.) Grun.	O	V	O	O	O	O	O	O	O	R	PP	S	
Diatoma vulgare var. *linearis* V.H.	O	R	O	O	O	O	O	O	O	R	PP	S	
DIDYMOSPHAENIA													
Didymosphenia geminata (Lyngb.) M. Schmidt	O	O	C	O	O	O	R	R	O	R	PP	S-I	Oligotrophic
DIPLONEIS													
Diploneis boldtiana Cl.	R	V	O	R	V	O	R	R	O	S	-	Sp-I	More common in old samples from Lake Michigan
Diploneis domblittensis (Grun.) Cl.	V	O	O	V	O	O	V	O	O	S	-	Sp-I	
Diploneis elliptica (Kütz.) Cl.	V	O	O	V	O	O	R	R	O	S	-	Sp-I	
Diploneis elliptica var. *pygmaea* A. Cl.	O	V	O	O	O	O	O	O	O	S		I	
Diploneis finnica (Ehr.) Cl.	V	O	O	V	O	O	R	O	O	S	-	Sp-I	Oligotrophic
Diploneis oblongella (Näg.) Ross	V	O	O	O	O	O	V	O	O	S	-	Sp-I	
Diploneis oculata (Bréb.) Cl.	R	V	O	R	V	O	R	R	O	S	-	Sp-I	
Diploneis ovalis (Hilse) Cl.	V	V	O	V	V	O	R	V	O	S		Sp-I	
Diploneis parma Cl.	V	V	O	R	V	O	R	V	O	S	-	Sp-I	Boreal, oligotrophic
Diploneis subovalis Cl.	V	V	O	O	O	O	O	O	O	S	-	Sp-I	
ENTOMONEIS													
Entomoneis ornata (J.W. Bail.) Reim.	R	R	R	O	R	R	O	O	O	SSv	T	I-D	Eurytopic
EPITHEMIA													
Epithemia adnata (Kütz.) Bréb.	R	R	R	O	V	O	O	O	O	PP	R	I-D	
Epithemia adnata var. *porcellus* (Kütz.) Patr.	V	R	V	O	V	O	O	O	O	PP	R	I-D	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Epithemia adnata var. *saxonica* (Kütz.) Patr.	V	V	V	0	V	0	V	0	0	PP	R	Sp-D	
Epithemia argus (Ehr.) Kütz.	V	0	0	0	0	0	0	0	0	PVa	PP	Sp-I	
Epithemia argus var. *alpestris* Grun.	V	V	0	0	0	0	V	0	0	PP	R	I-D	
Epithemia argus var. *longicornis* (Ehr.) Grun.	V	0	0	0	0	0	0	0	0	PV	PP	Sp-I	
Epithemia emarginata Andrews	V	0	0	0	0	0	0	0	0	PP	R	D	Previous reports fossil
Epithemia intermedia Fricke	C	A	R	R	R	R	0	0	0	PP	R	D-I	
Epithemia reichelti Fricke	R	0	0	R	0	0	0	0	0	PP	R	D-I	
Epithemia smithii Carruthers	R	V	0	C	V	0	V	0	0	PP	R	D-I	Distribution poorly known
Epithemia sorex Kütz.	0	0	V	0	0	V	0	0	0	PV	PP	Sp-I	Eutrophic-possibly allochthonous
Epithemia turgida (Ehr.) Kütz.	R	V	0	R	V	0	R	V	0	PP	R	D-I	
Epithemia turgida var. *granulata* (Ehr.) Brun	V	0	0	V	0	0	V	0	0	PP	R	D-I	
Epithemia turgida var. *westermannii* (Ehr.) Grun.	0	0	0	0	0	0	V	0	0	R	-	D-I	
EUNOTIA													
Eunotia arcus Ehr.	V	0	0	0	0	0	R	V	0	PP	S	Sp-I	
Eunotia arcus var. *bidens* Grun.	V	0	0	0	0	0	C	V	0	PP	S	Sp-I	
Eunotia arcus var. *fallax* Hust.	V	0	0	0	0	0	R	V	0	PP	S	Sp-I	L. Michigan historic samples only
Eunotia curvata (Kütz.) Lagerst.	V	0	0	0	0	0	R	V	0	PP	S	Sp-I	
Eunotia diodon Ehr.	V	0	0	0	0	0	R	V	0	PP	S	Sp-I	
Eunotia exigua (Bréb.) Rabh.	0	0	0	0	0	0	V	0	0	PP	S	Sp-I	
Eunotia flexuosa Bréb.	V	0	0	C	V	0	C	V	0	PP	S	Sp-I	
Eunotia flexuosa var. *eurycephala* Grun.	0	0	0	0	0	0	V	0	0	PP	-	Sp-I	
Eunotia formica Ehr.	R	0	0	R	0	0	R	0	0	R	PP	Sp-D	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Eunotia incisa W. Sm.	V	0	0	0	0	0	A	V	0	SS	R	Sp-I	L. Michigan sample, probably allochthonous
Eunotia microcephala Krasske	0	0	0	0	0	0	V	0	0	SS	-	Sp	
Eunotia naegelii Migula	0	0	R	0	0	0	R	0	0	PP	R	Sp-I	L. Michigan sample, probably allochthonous
Eunotia pectinalis (O. Müll.) Rabh.	0	0	0	0	0	0	R	0	0	PP	R	Sp	
Eunotia pectinalis var. *minor* (Kütz.) Rabh.	0	0	0	0	0	0	V	0	0	S	-	Sp	
Eunotia pectinalis var. *ventricosa* Grun.	0	0	0	0	0	0	V	0	0	S	-	Sp	
Eunotia perpusilla Grun.	0	0	0	0	0	0	V	0	0	S	-	Sp	
Eunotia praerupta Ehr.	R	R	0	R	0	0	R	R	0	R	PP	Sp-D	
Eunatia praerupta var. *bidens* (Ehr.) Grun.	0	0	0	0	0	0	R	V	0	R	PP	Sp	
Eunotia praerupta var. *inflata* Grun.	0	0	0	0	0	0	V	0	0	R	SS	Sp-I	
Eunotia pseudolunaris Venkt.	0	0	0	0	0	0	V	0	0	R	PP	I	
Eunotia praerupta var. *laticeps f. curta* Grun.	0	0	0	0	0	0	R	0	0	R	PP	I-D	
Eunatia septentrionalis Østr.	0	0	0	0	0	0	R	0	0	S	-	Sp	
Eunotia serra Ehr.	V	0	0	V	0	0	R	0	0	S	-	Sp-I	
Eunotia tenella (Grun.) Hust.	0	0	0	0	0	0	R	0	0	S	-	Sp	
Eunotia trinacria Krasske	0	0	V	0	0	0	0	0	0	PP	-	Sp	Probably allochthonous
Eunotia vanheurckii Patr.	0	0	V	0	0	0	R	V	0	S	R	Sp-I	L. Michigan sample, probably allochthonous
Eunotia vanheurckii var. *intermedia* (Krasske) Patr.	0	0	0	0	0	0	R	0	0	S	-	Sp	
FRAGILARIA													
Fragilaria brevistriata Grun.	R	C	C	R	R	C	R	R	R	S	T	Sp-I	
Fragilaria brevistriata var. *capitata* Hérib.	V	0	0	0	0	0	0	0	0	S	T	Sp-I	
Fragilaria brevistriata var. *inflata* (Pant.) Hust.	C	R	V	R	R	0	C	C	0	S	T	Sp-I	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Fragilaria capucina Desm.	R	A	D	R	A	D	V	R	A	S	T	Sp-I	Plankton dominant in shallow, eutrophic regions.
Fragilaria capucina var. *mesolepta* Rabh.	R	C	A	V	R	C	0	0	0	S	T		
Fragilaria constricta fo. *stricta* (A.Cl.) Hust.	0	0	0	0	0	0	V	0	0	S	R	Sp	Extreme oligotrophic
Fragilaria construens (Ehr.) Grun.	R	C	A	R	C	C	A	R	D	S	T	Sp-I	Great Lakes distribution unusual
Fragilaria construens var. *binodis* (Ehr.) Grun.	R	R	D	R	R	R	R	R	R	S	T	Sp-I	
Fragilaria construens var. *capitata* Hérib.	R	R	R	0	0	R	R	R	R	S	T	Sp-I	
Fragilaria construens var. *minuta* Temp. and M. Perag.	R	V	V	R	V	V	C	R	V	S	T	Sp-D	
Fragilaria construens var. *pumila* Grun.	R	V	V	R	V	V	R	V	V	S	T	Sp-I	
Fragilaria construens var. *subsalina* Hust.	V	V	V	0	V	V	V	V	V	S	T	Sp	
Fragilaria construens var. *venter* (Ehr.) Grun.	C	R	V	V	V	0	R	V	0	S	T	Sp-I	Common in fossil deposits
Fragilaria heideni Østr.	0	0	V	0	0	0	0	0	0	?	?	?	Distribution poorly known, perhaps allochthonous
Fragilaria heideni var. *istvanffyi* (Pant.) Hust.	0	0	V	0	0	0	0	0	0	?	?	?	
Fragilaria intermedia Grun.	R	R	C	R	R	R	R	R	R	S,R	T	I-D	
Fragilaria intermedia var. *continua* A. Cl.	0	0	0	0	0	0	R	R	0	S	T	Sp-I	
Fragilaria lapponica Grun.	R	R	0	0	0	0	R	R	0	S,R	T	Sp-I	
Fragilaria leptostauron (Ehr.) Hust.	C	R	R	C	R	V	C	R	R	S	R	Sp-D	
Fragilaria leptostauron var. *dubia* (Grun.) Hust.	V	V	V	V	V	V	V	V	V	S	R	I-D	
Fragilaria leptostauron var. *fossilis* (Grun.) Rehákova	R	V	V	R	V	0	R	V	0	S	R	Sp-D	
Fragilaria leptostauron var. *rhomboides* (Grun.) Hust.	0	V	0	0	0	0	0	0	0	S	R	D-I	
Fragilaria pantocsekii var. *binodis* (Pant.) A. Cl.	R	V	0	V	0	0	R	V	0	S	R	Sp-I	
Fragilaria pinnata Ehr.	C	A	D	C	A	D	C	A	A	S	R	Sp-D	
Fragilaria pinnata var. *intercedens* (Grun.) Hust.	R	V	0	R	V	0	V	V	0	S	R	Sp-I	
Fragilaria pinnata var. *lancettula* (Schum.) Hust.	R	C	A	V	R	C	R	R	R	S	R	Sp-I	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Fragilaria spinosa Skv.	0	V	0	0	0	0	0	0	0	?	?	?	Distribution poorly known, perhaps allochthonous
Fragilaria vaucheriae (Kütz.) Peters.	C	R	R	C	C	R	A	C	R	R,PP	T	Sp-D	
Fragilaria vaucheriae var. *capitellata* (Grun.) Patr.	C	R	V	C	R	V	A	C	R	R,PP	T	S-I	
Fragilaria vaucheriae var. *lanceolata* A. Meyer	V	0	0	0	0	0	0	0	0	R	-	I	
Fragilaria vaucheriae var. *truncata* (Grev.) Grun.	0	0	V	0	0	0	0	0	0	R	T	S-I	
Fragilaria virescens Ralfs	V	0	0	V	0	0	R	V	0	S	R	Sp-I	
Fragilaria virescens var. *capitata* Østr.	0	0	0	0	0	0	V	0	0	S	R	Sp	
Fragilaria virescens var. *mesolepta* (Rabh.) Schönf.	V	0	0	0	0	0	0	0	0	S	R	I	
Fragilaria virescens var. *oblongella* Grun.	0	0	0	0	0	0	R	0	0	S	R	Sp-I	
FRUSTULIA													
Frustulia rhomboides (Ehr.) DeT.	V	0	0	0	0	0	V	0	0	S	-	Sp-I	
Frustulia rhomboides var. *amphipleuroides* (Grun.) DeT.	R	0	0	R	0	0	R	0	0	S	-	Sp-I	
Frustulia rhomboides var. *crassinervia* (Bréb.) Ross	0	0	0	0	0	0	R	0	0	S	PP	Sp-I	
Frustulia rhomboides var. *saxonica* (Rabh.) DeT.	V	0	0	V	0	0	R	0	0	S	PP	Sp-I	
Frustulia vulgaris (Thw.) DeT.	R	V	0	V	0	0	V	0	0	S	-	Sp-I	
Frustulia vulgaris var. *capitata* Krasske	0	0	0	0	0	0	V	0	0	S	-	Sp	
Frustulia weinholdii Hust.	V	0	0	0	0	0	0	0	0	S	-	Sp-I	Historic samples only
GOMPHONEMA													
Gomphonema abbreviatum Ag.	0	V	0	0	0	0	0	0	0	Ra	PPa	S-I	
Gomphonema abbreviatum var. *inflata* Hust.	C	V	0	0	0	0	0	0	0	Ra	PPa	D	
Gomphonema acuminatum Ehr.	0	0	0	0	0	0	R	0	0	Ra	PPa	I-D	
Gomphonema acuminatum var. *brebissonii* (Kütz.) Grun.	0	0	0	0	0	0	R	0	0	Ra	PPa	Sp-I	
Gomphonema acuminatum var. *coronata* (Ehr.) Rabh.	V	0	0	V	0	0	R	V	0	Ra	PPa	Sp-I	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Gomphonema acuminatum var. *pusillum* Grun.	0	0	V	0	0	0	R	V	0	Ra	PPa	Sp-I	
Gomphonema acuminatum var. *trigonocephala* (Ehr.) Grun.	0	0	0	0	0	0	V	0	0	Ra	PPa	Sp	
Gomphonema affine Kütz.	0	0	0	V	0	0	0	0	0	Ra	PPa	Sp-I	
Gomphonema affine var. *insigne* (Greg.) Andrews	0	0	0	V	0	0	0	0	0	Ra	PPa	Sp-I	
Gomphonema angustatum (Kütz.) Rabh.	C	R	R	C	R	R	R	R	R	Ra	PPa	I-S	
Gomphonema angustatum var. *productum* Grun.	R	V	V	V	0	0	R	V	V	Ra	PPa	Sp-I	
Gomphonema angustatum var. *sarcophagus* (Greg.) Grun.	0	0	V	0	0	0	0	0	0	Ra	PPa	Sp-I	
Gomphonema clevei Fricke	V	V	V	0	0	0	0	0	0	R	S	I	
Gomphonema gracile Ehr.	R	R	V	R	R	V	R	R	R	Ra	PPa	Sp-I	
Gomphonema gracile var. *cymbelloides* Grun.	0	0	V	0	0	0	0	0	0	Ra	-	I	
Gomphonema gracile var. *naviculacea* (W. Sm.) Cl.	R	0	0	R	0	0	C	R	0	Ra	PPa	Sp-I	
Gomphonema grovei M. Schmidt	0	R	R	0	0	0	0	0	0	?	?		Previously reported as fossil, perhaps allochthonous
Gomphonema helveticum Brun	0	0	0	0	0	0	R	0	0	Ra	PPa	Sp-I	
Gomphoneis eriense (Grun.) Skv. and Meyer	0	0	V	0	0	0	0	0	0	R	PPa	S-I	
Gomphoneis herculeana (Ehr.) Cl.	C	R	V	C	R	V	C	R	V	R	PPa	S-I	
Gomphonema intricatum Kütz.	A	R	V	A	R	V	D	D	R	Ra	PPa	D-Sp	
Gomphonema intricatum var. *dichotomum* (Kütz.) Grun.	R	V	0	R	0	0	R	R	V	Ra	-	D-Sp	
Gomphonema intricatum var. *fossilis* Pant.	0	0	0	0	0	0	C	0	0	Ra	-	Sp	
Gomphonema intricatum var. *pumila* Grun.	C	R	V	C	R	V	R	R	0	Ra	S	D-Sp	
Gomphonema intricatum var. *vibrio* (Ehr.) Cl.	0	0	0	R	V	0	C	R	V	Ra	PPa	Sp-I	
Gomphonema lanceolatum Ehr.	R	V	V	R	V	V	V	V	0	Ra	PPa	I-D	
Gomphonema lanceolatum var. *insignis* (Greg.) Cl.	V	0	0	0	0	0	0	0	0	Ra	-	I-D	
Gomphonema longiceps Ehr.	V	0	0	0	0	0	0	0	0	Ra	-	I	Historic samples only

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	Lake Michigan II	Lake Michigan III	Lake Huron I	Lake Huron II	Lake Huron III	Lake Superior I	Lake Superior II	Lake Superior III	Primary habitats	Secondary habitats	Depth range	Notes
Gomphonema longiceps var. *subclavata* Grun.	V	0	0	0	0	0	0	0	0	Ra	-	I	Historic samples only
Gomphonema manubrium Fricke	V	0	0	C	V	0	R	R	0	Ra	S	D-Sp	
Gomphonema olivaceoides Hust.	A	R	V	A	R	V	A	R	V	Ra	PPa	D-I	More abundant in historic L. Michigan samples
Gomphonema olivaceoides var. *cochleariformis* Mang.	0	0	0	0	0	0	A	0	0	Ra	-		
Gomphonema olivaceum (Lyngb.) Kütz.	C	R	R	C	R	R	R	R	R	Ra	PPa	D-Sp	Widely distributed
Gomphonema olivaceum var. *calcarea* (Cl.) Cl.	C	R	R	A	R	R	V	V	V	Ra	PPa	D-Sp	
Gomphonema parvulum (Kütz.) Kütz.	R	R	R	R	R	R	A	R	V	Ra	PPa	Sp-I	
Gomphonema parvulum var. *exilissima* Grun.	0	0	0	0	0	0	C	R	0	Ra	-	Sp-I	
Gomphonema parvulum var. *micropus* (Kütz.) Cl.	V	V	V	0	0	0	0	0	0	Ra	S	I-D	
Gomphonema quadripunctatum (Østr.) Wisl.	0	0	0	0	0	0	R	V	0	Ra	-	I-D	
Gomphonema subclavatum fo. *gracilis* (Hust.) Woodhead and Tweed	0	0	0	0	0	0	V	0	0	Ra	S	Sp-I	
Gomphonema subclavatum (Grun.) Grun.	V	0	0	0	0	0	R	V	0	Ra	PPa	D-I	
Gomphonema sphaerophorum Ehr.	0	0	V	V	0	0	R	R	0	Ra	-	D-I	
Gomphonema subtile Ehr.	V	V	0	R	V	0	R	R	0	Ra	-	Sp-I	
Gomphonema subtile var. *sagitta* (Schum.) Cl.	V	0	0	0	0	0	R	R	0	Ra	S	Sp-I	
Gomphonema tergestinum (Grun.) Fricke	0	0	V	0	0	0	V	0	0	Ra	S	Sp-I	
Gomphonema truncatum Ehr.	V	0	0	0	0	0	R	V	0	Ra	PPa	I-D	
Gomphonema truncatum var. *capitatum* (Ehr.) Patr.	0	0	V	0	0	0	R	R	0	Ra	PPa	Sp-I	
Gomphonema turris Ehr.	0	0	0	0	0	0	V	0	0	Ra	-	Sp	
Gomphonema ventricosum Greg.	0	0	0	0	0	0	C	0	0	Ra	PPa	I-D	
GYROSIGMA													
Gyrosigma acuminatum (Kütz.) Rabh.	R	R	V	R	R	V	0	0	0	Sv	T	I-D	
Gyrosigma attenuatum (Kütz.) Rabh.	V	V	V	V	V	V	0	0	0	Sv	T	I-D	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	Lake Michigan II	Lake Michigan III	Lake Huron I	Lake Huron II	Lake Huron III	Lake Superior I	Lake Superior II	Lake Superior III	Primary habitats	Secondary habitats	Depth range	Notes
Gyrosigma nodiferum (Grun.) Reim.	V	V	V	0	0	0	0	0	0	Sv	T	I-D	
Gyrosigma scalproides (Rabh.) Cl.	V	R	V	0	0	0	V	0	0	Sv	T	I-D	
Gyrosigma sciotense (Sulliv. and Wormley) Cl.	V	R	R	0	0	0	V	0	0	Sv	T	D-I	
Gyrosigma spencerii (Quek.) Griff and Henfr.	R	V	V	0	0	0	V	0	0	Sv	T	I-D	
Gyrosigma spencerii var. *curvula* (Grun.) Reim.	C	R	V	V	V	V	V	V	0	Sv	T	D-I	
Gyrosigma temperei Cl.	0	V	V	0	0	0	0	0	0	Sv	T	I-D	
Gyrosigma wormleyi (Sulliv.) Boyer	0	0	V	0	0	0	0	0	0	Sv	T	I	
HANNAEA													
Hannaea arcus (Ehr.) Patr.	R	0	0	R	0	0	A	R	0	Ra	T	Sp-I	
Hannaea arcus var. *amphioxys* (Rabh.) Patr.	V	0	0	0	0	0	0	0	0	Ra	T	Sp-I	
Hannaea arcus var. *linearis* Holmboe	0	0	0	0	0	0	0	0	0	Ra	-	I-D	
HANTZSCHIA													
Hantzschia amphioxys (Ehr.) Grun.	V	V	V	V	0	V	V	V	V	Sv	-	Sp-I	Very widely distributed
Hantzschia amphioxys var. *capitata* O. Müll.	V	V	V	0	0	0	V	0	0	Sv	-	Sp-I	
MASTOGLOIA													
Mastogloia grevillei W. Sm.	R	R	R	0	0	0	0	0	0	Sv	-	Sp-I	
Mastogloia smithii Thw.	V	V	V	0	0	0	0	0	0	Sv	-	Sp-I	
Mastogloia smithii var. *amphicephala* Grun.	V	V	0	V	0	0	0	0	0	Sv	-	Sp-I	
Mastogloia smithii var. *lacustris* Grun.	R	R	0	R	V	0	V	V	0	Sv	-	Sp-I	
MELOSIRA													
Melosira arenaria Moore	0	0	0	0	0	0	V	0	0	SS	-	D-Sp	Oligotrophic
Melosira undulata (Ehr.) Kütz.	V	0	0	0	0	0	V	0	0	S	-	D	More common in fossil material from L. Superior

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	Lake Michigan II	Lake Michigan III	Lake Huron I	Lake Huron II	Lake Huron III	Lake Superior I	Lake Superior II	Lake Superior III	Primary habitats	Secondary habitats	Depth range	Notes
Melosira undulata var. *normannii* Arnott	V	O	O	O	O	O	V	O	O	S	-	D	
Melosira varians Ag.	O	R	C	O	R	C	O	O	R	S	T	S-I	
MERIDION													
Meridion circulare (Grev.) Ag.	V	V	V	V	O	O	V	V	V	R	S	Sp-I	
Meridion circulare var. *constrictum* (Ralfs) V.H.	V	V	V	O	O	O	V	V	O	R	S	Sp-I	
NAVICULA													
Navicula aboensis (Cl.) Hust.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Navicula absoluta Hust.	O	O	O	O	O	O	R	O	O	Sv	-	Sp-I	
Navicula acceptata Hust.	R	R	V	V	O	O	R	V	O	Sv	-	Sp-I	
Navicula accomoda Hust.	V	V	V	O	O	O	O	O	O	Sv	-	I-Sp	
Navicula ambigua Ehr.	O	O	V	O	O	O	V	V	O	Sv	-	I-Sp	
Navicula americana Ehr.	O	O	O	O	O	O	V	O	O	Sv	-	Sp-I	
Navicula amphibola var. *perrieri* Perag. and Hérib.	V	O	O	O	O	O	O	O	O	Sv	-	I	
Navicula anglica Ralfs	R	R	V	R	O	O	V	V	O	Sv	T	I-Sp	Much more common in historic L. Michigan samples
Navicula anglica var. *signata* Hust.	R	R	R	O	O	O	V	V	O	Sv	T	D-I	
Navicula anglica var. *subsalsa* (Grun.) Cl.	V	V	O	O	O	O	O	O	O	Sv	-	I-D	
Navicula angustata W. Sm.	V	O	O	O	O	O	V	O	O	Sv	-	Sp-I	
Navicula aurora Sov.	R	V	O	R	O	O	R	V	O	Sv	-	Sp-I	Much more common in historic L. Michigan samples
Navicula bacillum Ehr.	V	V	O	V	O	O	R	V	O	Sv	-	Sp-I	Much more common in historic L. Michigan samples
Navicula balcanica Hust.	R	V	O	O	O	O	O	O	O	Sv	-	Sp-I	Much more common in historic L. Michigan samples
Navicula begeri Krasske	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Navicula bryophila Peters.	V	V	O	O	O	O	O	O	O	S	PB	I-D	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Navicula capitata Ehr.	V	V	R	V	V	V	V	V	V	Sv	-	I-D	
Navicula capitata var. *hungarica* (Grun.) Ross	V	V	0	V	0	0	V	V	0	Sv	-	I-D	
Navicula capitata var. *luneburgensis* (Grun.) Patr.	V	V	R	0	0	R	V	V	V	Sv	-	I-D	
Navicula capsa Hohn	V	0	0	0	0	0	V	0	0	Sv	-	Sp-I	
Navicula caroliniana Patr.	0	0	V	0	0	0	0	0	0	Sv	T	Sp-I	Perhaps allochthonous
Navicula circumtexta Meist.	0	0	V	0	0	0	0	0	0	Sv	-	Sp-I	Halophilic
Navicula citrus Krasske	0	0	V	0	0	0	0	0	0	Sv	-	Sp-I	
Navicula clementis Grun.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Navicula clementis var. *linearis* Brander	0	0	V	0	0	0	V	0	0	Sv	-	Sp-I	
Navicula clementis var. *quadristigmata* Mang.	0	0	0	0	0	0	V	0	0	Sv	-	Sp-I	
Navicula cocconeiformis Greg.	V	0	0	V	0	0	C	R	V	Sv	-	Sp-I	
Navicula confervacea (Kütz.) Grun.	0	0	R	0	0	V	0	0	0	Sv	PP	Sp	Possibly allochthonous
Navicula contenta Grun.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Navicula contenta var. *biceps* (Arn.) Grun.	0	V	0	0	0	0	0	0	0	PB	-	D	In deep living bryophyte communities
Navicula costulata Cl. and Grun.	R	V	0	0	0	0	0	0	0	Sv	-	Sp-I	Much more common in historic L. Michigan samples
Navicula cryptocephaloides Hust.	V	0	0	0	0	0	0	0	0	Sv	-	I	
Navicula cryptocephala Kütz.	R	V	V	V	V	V	R	V	V	Sv	-	Sp-I	Widely distributed
Navicula cryptocephala var. *intermedia* V.H.	V	V	R	V	R	R	0	0	0	Sv	-	Sp-I	Widely distributed
Navicula cryptocephala var. *lancettula* (Schum.) Grun.	V	0	0	0	0	0	0	0	0	Sv	-	I	
Navicula cryptocephala var. *veneta* (Kütz.) Rabh.	V	V	R	V	V	R	V	V	R	Sv	-	Sp-I	
Navicula cuspidata (Kütz.) Kütz.	V	V	V	V	V	V	V	V	V	Sv	-	Sp-I	Widely distributed
Navicula cuspidata var. *major* Meist.	V	0	V	0	0	0	0	0	0	Sv	-	Sp-I	
Navicula decussis Østr.	V	R	R	V	V	V	V	V	V	Sv	T	Sp-I	
Navicula elginensis (Greg.) Ralfs	0	0	V	0	0	0	V	0	0	Sv	-	Sp-I	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Navicula elginensis var. *lata* (M. Perag.) Patr.	0	0	0	0	0	0	V	0	0	Sv	-	Sp-I	
Navicula elginensis var. *rostrata* (A. Mayer) Patr.	0	0	0	0	0	0	V	0	0	Sv	-	Sp-I	
Navicula exigua (Greg.) Grun.	0	0	V	0	0	0	0	0	0	Sv	-	Sp-I	
Navicula exigua var. *capitata* Patr.	V	V	0	0	0	0	V	0	0	Sv	-	Sp-I	
Navicula exiguiformis Hust.	R	V	V	0	0	0	0	0	0	Sv	T	I-Sp	More common in historic Lake Michigan samples
Navicula explanata Hust.	R	V	V	R	0	0	R	R	V	Sv	-	I-Sp	
Navicula farta Hust.	V	0	0	0	0	0	C	R	V	Sv	-	Sp-I	
Navicula fracta Hust.	R	0	0	0	0	0	R	V	0	Sv	-	I-Sp	
Navicula gastriformis Hust.	0	0	V	0	0	0	0	0	0	Sv	-	I	
Navicula gastrum (Ehr.) Kütz.	V	V	V	0	0	0	V	V	V	Sv	-	Sp-I	
Navicula gastrum var. *signata* Hust.	R	V	0	R	0	0	0	0	0	Sv	-	I	
Navicula gibbosa Hust.	0	0	V	0	0	0	0	0	0	Sv	-	Sp-I	Probably allochthonous
Navicula globosa Meist.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Navicula gottlandica Grun.	0	0	R	0	0	0	0	0	V	Sv	-	Sp-I	
Navicula graciloides A. Mayer	V	R	R	0	V	R	0	V	0	Sv	-	Sp-I	
Navicula gregaria Donk.	0	V	R	0	0	R	0	0	0	Sv	-	Sp-I	Halophilic
Navicula grimmei Krasske	0	V	R	0	0	0	0	0	0	Sv	-	Sp-I	
Navicula gysingensis Foged	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Navicula hambergii Hust.	V	0	0	0	0	0	0	0	0	Sv	T	Sp-I	Historic samples only
Navicula hassiaca Krasske	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Navicula hasta Pant.	V	0	0	0	0	0	0	0	0	Sv	-	I-D	
Navicula heufleri Grun.	0	V	0	0	0	0	0	V	0	Sv	-	Sp	
Navicula heufleri var. *leptocephala* (Bréb.) Patr.	0	0	V	0	0	0	0	0	0	Sv	-	Sp-I	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	Lake Michigan II	Lake Michigan III	Lake Huron I	Lake Huron II	Lake Huron III	Lake Superior I	Lake Superior II	Lake Superior III	Primary habitats	Secondary habitats	Depth range	Notes
Navicula hustedtii fo. *obtusa* (Hust.) Hust.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Navicula imbricata Bock	V	0	0	0	0	0	0	0	0	?	?	?	Perhaps allochthonous
Navicula insociabilis var. *dissipatoides* Hust.	V	0	0	0	0	0	0	0	0	Sv	-	I	
Navicula integra (W. Sm.) Ralfs	0	0	V	0	0	0	0	0	0	Sv	-	Sp-I	
Navicula intractata Hust.	0	0	0	0	0	0	V	0	0	Sv	-	Sp-I	
Navicula jaernefeltii Hust.	R	0	0	R	0	0	C	V	0	Sv	-	Sp-D	
Navicula krasskei Hust.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Navicula lacustris Greg.	R	0	0	V	0	0	V	0	0	Sv	-	I	
Navicula lanceolata (Ag.) Kütz.	R	R	R	R	R	R	R	R	R	Sv	T	Sp-I	Widely distributed
Navicula lanceolata var. *cymbula* (Donk.) Cl.	V	0	V	0	0	0	V	V	0	Sv	-	Sp-I	
Navicula latens Krasske	V	R	V	0	0	0	0	0	0	Sv	-	Sp-I	
Navicula levanderi Hust.	V	0	0	0	0	0	V	0	0	Sv	-	Sp-I	Historic L. Michigan sample only
Navicula luzonensis Hust.	V	0	0	0	0	0	0	0	0	Sv	-	I	
Navicula mediocris Krasske	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Navicula menisculus Schum.	V	0	0	0	0	0	V	0	0	Sv	T	I	
Navicula menisculus var. *obtusa* Hust.	R	V	V	0	0	0	0	0	0	Sv	-	I	
Navicula menisculus var. *upsaliensis* Grun.	R	R	R	V	V	R	V	R	R	Sv	T	I	
Navicula micropupula Choln.	V	V	0	0	0	0	0	0	0	Sv	-	I-D	
Navicula minima Grun.	R	V	V	V	V	V	R	V	V	Sv	-	Sp-I	Widely distributed
Navicula minima var. *okamurae* Skv.	0	0	V	0	0	0	0	0	0	Sv	-	I	
Navicula minnewaukonensis Elmore	V	0	0	0	0	0	0	0	0	Sv	-	I	
Navicula minuscula Grun.	V	0	0	0	0	0	0	0	0	Sv	-	I	
Navicula minuscula var. *alpestris* Hust.	V	0	0	0	0	0	V	0	0	Sv	-	Sp-I	

(continued)

TABLE 1 (continued)

Name	Lake Michigan			Lake Huron			Lake Superior			Primary habitats	Secondary habitats	Depth range	Notes
	I	II	III	I	II	III	I	II	III				
Navicula minusculoides Hust.	V	0	0	0	0	0	0	0	0	Sv	-	D-I	
Navicula monoculata Hust.	V	0	0	0	0	0	0	0	0	Sv	R	D	
Navicula muraliformis Hust.	V	0	0	0	0	0	0	0	0	Sv	R	D	
Navicula mutica Kütz.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	Possibly allochthonous
Navicula mutica var. *cohnii* (Hilse) Grun.	R	V	0	R	0	0	R	V	0	Sv	R	Sp-I	
Navicula mutica var. *tropica* Hust.	V	0	V	0	0	0	0	0	0	Sv	R	Sp-I	
Navicula mutica var. *undulata* (Hilse) Grun.	0	0	0	0	0	0	R	0	0	Sv	R	Sp	
Navicula muticoides Hust.	V	0	0	0	0	0	0	0	0	Sv	-	Sp	
Navicula muticopsis V.H.	V	0	0	0	0	0	R	0	0	Sv	-	Sp-I	
Navicula neoventricosa Hust.	0	0	0	V	0	0	0	0	0	Sv	-	Sp-I	
Navicula nyassensis fo. *minor* O. Müll.	V	0	0	0	0	0	R	0	0	Sv	-	Sp-I	
Navicula oblonga (Kütz.) Kütz.	V	V	0	V	V	0	V	V	0	Sv	-	Sp-I	Widely distributed
Navicula odiosa Wallace	0	V	R	0	0	0	0	0	0	Sv	-	I-Sp	
Navicula oppugnata Hust.	R	V	V	R	0	0	R	V	0	Sv	-	Sp-I	
Navicula ordinaria Hust.	V	0	0	0	0	0	0	0	0	Sv	-	I	
Navicula paanaensis A. Cl.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Navicula paca Hohn and Hellerm.	V	0	0	0	0	0	0	0	0	Sv	T	D-I	
Navicula paludosa Hust.	C	R	V	R	R	0	R	R	0	Sv	R	D-Sp	
Navicula pelliculosa Hilse	0	V	V	0	V	0	0	0	0	Sv	-	Sp-I	
Navicula peratomus Hust.	R	0	V	0	0	0	0	0	0	Sv	-	D-I	
Navicula perpusilla (Kütz.) Grun.	V	0	0	0	0	0	V	0	0	Sv	-	Sp-I	
Navicula placenta Ehr.	0	0	V	0	0	0	0	0	0	Sv	-	Sp-I	
Navicula placentula (Ehr.) Kütz.	R	V	V	V	0	0	0	0	0	Sv	-	Sp-I	More abundant in historic L. Michigan samples

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Navicula placentula var. *rostrata* A. Mayer	V	R	V	0	0	0	V	0	0	Sv	-	Sp-I	
Navicula platycephala O. Müll.	V	0	0	0	0	0	0	0	0	Sv	-	I-D	
Navicula platystoma var. *pantocsekii* Wils. and Kolbe	V	R	R	V	V	0	0	0	0	Sv	-	I-D	
Navicula potzgeri Reim.	0	V	0	0	0	0	0	0	0	Sv	-	I-D	
Navicula protracta (Grun.) Cl.	V	V	V	0	0	0	0	0	0	Sv	-	Sp-D	
Navicula protracta var. *elliptica* Gallik	V	R	R	0	0	V	0	0	0	Sv	-	I-D	
Navicula protracta fo. *subcapitata* (Wils. and Por.) Hust.	R	V	V	0	0	0	0	V	0	Sv	-	I-D	
Navicula pseudoclementis Hust.	V	0	0	0	0	0	R	0	0	Sv	-	Sp-I	
Navicula pseudoscutiformis Hust.	R	V	V	R	0	0	R	R	V	Sv	R	Sp-I	
Navicula pseudoventralis Hust.	0	0	V	0	0	0	V	0	0	Sv	-	Sp-I	
Navicula pupula Kütz.	R	R	V	R	V	0	R	R	V	Sv	-	Sp-I	Widely distributed
Navicula pupula var. *aquaeductae* (Krasske) Hust.	0	0	V	0	0	0	0	0	0	Sv	-	I	
Navicula pupula var. *capitata* Hust.	R	R	V	R	R	V	R	V	V	Sv	-	Sp-I	
Navicula pupula var. *elliptica* Hust.	R	V	0	R	V	0	0	0	0	Sv	-	I-D	
Navicula pupula var. *mutata* (Krasske) Hust.	R	V	V	0	0	0	0	0	0	Sv	-	Sp-I	More common in historic L. Michigan collections
Navicula pupula var. *rectangularis* (Greg.) Cl.	R	V	V	R	V	0	R	R	0	Sv	-	Sp-I	
Navicula pupula var. *rostrata* Hust.	R	V	V	V	V	0	V	0	0	Sv	-	Sp-I	More common in historic L. Michigan samples.
Navicula pygmaea Kütz.	0	V	R	0	0	V	0	0	0	Sv	-	Sp-I	Halophilic
Navicula quadripartita Hust.	0	0	V	0	0	0	0	0	0	Sv	-	Sp	
Navicula radiosa Kütz.	C	C	R	C	C	R	C	C	R	Sv	T	I-D	
Navicula radiosa var. *parva* Wallace	R	0	0	R	0	0	R	0	0	Sv	-	I-D	
Navicula radiosa var. *tenella* (Bréb.) Cl. and Möll.	C	R	R	C	R	R	C	R	R	Sv	T	Sp-D	
Navicula recondita Torka	V	0	0	0	0	0	0	0	0	R	-	D	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Navicula reinhardtii Grun.	V	V	R	V	V	R	V	V	V	Sv	-	Sp-I	
Navicula reinhardtii var. *elliptica* Hérib.	V	V	R	V	V	V	V	V	V	Sv	-	Sp-I	
Navicula rhynchocephala Kütz.	R	0	0	R	0	0	R	V	0	Sv	-	Sp-I	Only historic L. Michigan samples
Navicula rotunda Hust.	R	V	V	R	V	V	V	V	0	Sv	-	Sp-I	
Navicula salinarum Grun.	V	0	0	0	0	0	0	0	0	Sv	-	I	Probably allochthonous
Navicula schmassmannii Hust.	R	0	0	0	0	0	0	0	0	R	Sv	D	
Navicula schoenfeldii Hust.	0	0	V	0	0	0	0	0	0	Sv	-	Sp-I	
Navicula scutelloides W. Sm.	R	C	R	V	R	V	R	R	R	Pv	S	Sp-D	
Navicula scutiformis Grun.	0	0	0	V	0	0	V	0	0	Sv	-	Sp-I	
Navicula semenoides Hust.	V	0	0	V	0	0	R	V	0	Sv	-	D-I	
Navicula seminuloides Hust.	R	V	0	R	V	0	R	V	V	Sv	-	D-I	
Navicula seminulum Grun.	V	R	R	V	R	V	0	0	0	Sv	-	I-Sp	
Navicula seminulum var. *intermedia* Hust.	V	0	0	V	0	0	V	0	0	Sv	-	D-I	
Navicula similis Krasske	0	V	0	0	0	0	V	R	0	Sv	-	Sp-I	
Navicula simplex Krasske	0	0	V	0	0	0	0	0	0	Sv	-	Sp-I	
Navicula skabitschewskyi Sabelina	V	0	0	V	0	0	R	V	0	Sv	-	Sp-D	
Navicula stroemii Hust.	R	V	V	R	V	0	R	R	0	Sv	-	Sp-D	
Navicula stroesei (Østr.) A. Cl.	R	V	0	R	V	0	R	R	R	Sv	-	Sp-I	
Navicula splendicula Van Land.	R	V	V	0	0	0	0	0	0	Sv	-	I-D	
Navicula subcostulata Hust.	0	V	0	0	0	0	0	0	0	Sv	-	I	
Navicula subhamulata Grun.	R	V	V	R	0	0	V	V	0	Sv	-	Sp-I	
Navicula submuralis Hust.	V	0	0	0	0	0	0	0	0	Sv	-	I-D	Historic L. Michigan samples only
Navicula suboccultа Hust.	R	V	0	0	0	0	0	0	0	Sv	R	D-I	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Navicula subrhynchocephala Hust.	0	V	0	0	0	0	0	0	0	Sv	-	I	
Navicula subrotundata Hust.	V	0	0	V	0	0	R	0	0	Sv	-	Sp-I	
Navicula subsulcata Hust.	0	0	V	0	0	0	0	0	0	Sv	-	I	
Navicula subtilissima Cl.	0	0	0	0	0	0	V	0	0	PB	-	Sp	usually in Sphagnum sp.
Navicula tantula Hust.	V	R	R	0	V	R	0	V	R	Sv	-	Sp-I	
Navicula tecta Krasske	0	0	0	0	0	0	V	0	0	Sv	-	Sp-I	
Navicula terminata Hust.	0	0	V	0	0	0	0	0	0	Sv	-	Sp-I	Probably allochthonous
Navicula tridentula Krasske	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Navicula tridentula var. *parallela* Krasske	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Navicula tripunctata (O.F. Müll.) Bory	C	R	R	C	R	R	R	R	R	Sv	-	D-Sp	
Navicula tripunctata var. *cuneata* (Lauby) Stoerm. and Yang	0	R	R	0	0	0	0	0	0	Sv	-	I-D	
Navicula tripunctata var. *schizonemoides* (V.H.) Patr.	V	R	V	V	R	V	0	0	0	Sv	-	I-D	
Navicula tuscula Ehr.	R	V	V	V	V	V	V	V	V	Sv	-	Sp-I	More common in historic L. Michigan samples.
Navicula tuscula fo. *minor* Hust.	V	R	R	0	V	V	0	0	0	Sv	-	I-D	
Navicula tuscula fo. *obtusa* Hust.	R	V	V	R	V	0	V	0	0	Sv	-	I-D	
Navicula tuscula var. *rostrata* Hust.	V	V	0	0	0	0	0	0	0	Sv	-	I-D	
Navicula vanheurckii Patr.	0	V	V	0	0	0	0	0	0	Sv	-	D-I	May be misidentified RV of Achnanthes bioreti
Navicula variostriata Krasske	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Navicula ventosa Hust.	0	0	V	0	0	0	0	0	0	Sv	-	Sp-I	
Navicula ventralis Krasske	0	0	V	0	0	0	0	V	0	Sv	-	I-Sp	
Navicula ventralis fo. *simplex* Hust.	0	0	0	0	0	0	0	V	0	Sv	-	Sp	
Navicula viridula (Kütz.) Ehr.	V	R	V	V	R	V	0	V	V	Sv	-	Sp-I	
Navicula viridula var. *avenacea* (Bréb.) V.H.	V	R	R	0	0	V	0	0	0	Sv	-	I	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Navicula viridula var. *linearis* Hust.	V	R	V	0	V	0	V	V	0	Sv	-	I-Sp	
Navicula virdula var. *rostellata* (Kütz.) Cl.	0	V	V	0	0	0	0	V	0	Sv	-	I-Sp	
Navicula vitabunda Hust.	0	0	0	0	0	0	V	0	0	Sv	-	I-Sp	
Navicula vulpina Kütz.	V	V	0	V	0	0	R	V	V	Sv	-	I-Sp	
Navicula wittrockii (Lagerst.) Temp. and M. Perag.	R	V	0	R	V	0	R	V	0	Sv	-	I-Sp	
Navicula zanoni Hust.	V	R	R	0	0	0	0	0	0	Sv	-	I-Sp	
NEIDIUM													
Neidium affine (Ehr.) Pfitz.	R	0	0	R	0	0	R	V	0	Sv	-	I-D	More common in historic L. Michigan samples
Neidium affine var. *amphirhynchus* (Ehr.) Cl.	0	0	0	0	0	0	R	0	0	Sv	-	Sp	
Neidium affine var. *humerus* Reim.	R	0	0	R	0	0	R	0	0	Sv	-	Sp-I	Historic L. Michigan sample only
Neidium affine var. *undulatum* (Grun.) Cl.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Neidium binode (Ehr.) Hust.	V	V	0	0	0	0	0	0	0	Sv	-	I	
Neidium bisulcatum (Lagerst.) Cl.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Neidium bisulcatum var. *baicalense* (Skv. and Meyer) Reim.	V	0	0	0	0	0	V	0	0	Sv	-	Sp-I	Historic L. Michigan sample only
Neidium calvum Østr.	V	0	0	0	0	0	V	0	0	Sv	-	Sp-I	
Neidium distincte-punctatum Hust.	0	0	0	V	0	0	V	0	0	Sv	-	D-I	
Neidium dubium (Ehr.) Cl.	V	V	V	0	V	V	V	V	0	Sv	-	Sp-D	
Neidium dubium fo. *constrictum* Hust.	V	V	0	V	0	0	V	V	0	Sv	-	Sp-D	
Neidium hitchcockii (Ehr.) Cl.	V	0	0	V	0	0	V	V	0	Sv	-	Sp-I	
Neidium iridis (Ehr.) Cl.	V	V	0	V	0	0	V	V	0	Sv	-	Sp-I	
Neidium iridis var. *amphigomphus* (Ehr.) A. Mayer	V	V	0	0	V	0	V	V	0	Sv	-	Sp-I	
Neidium iridis var. *vernalis* Reich.	V	0	0	V	0	0	V	V	0	Sv	-	Sp-I	
Neidium kozolwi Meresch.	V	0	0	0	0	0	0	0	0	Sv	-	I-D	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Neidium kozlowi var. *baicalensis* fo. *robusta* Stoerm.	V	O	O	O	O	O	O	O	O	Sv	-	D	
Neidium ladogense (Cl.) Stoerm. and Yang	O	O	V	V	O	O	V	V	O	Sv	-	Sp-I	
Neidium sacoense Reim.	V	O	O	O	O	O	O	O	O	S	-	D-I	
Neidium temperei Reim.	O	O	O	O	O	O	V	O	O	S	-	Sp-I	
NITZSCHIA													
Nitzschia acula Hantz.	V	R	V	V	V	V	O	V	V	Sv	T	I-D	
Nitzschia amphibia Grun.	C	C	R	R	R	R	O	V	V	Sv	-	I-D	
Nitzschia amphibia var. *fossilis* Grun.	O	O	O	O	O	O	R	R	O	Sv	-	Sp-I	
Nitzschia angustata (W. Sm.) Grun.	R	R	V	R	R	V	O	V	V	Sv	-	I-Sp	
Nitzschia angustata var. *acuta* Grun.	R	R	O	C	R	O	A	C	V	Sv	R	I-D	
Nitzschia apiculata (Greg.) Grun.	O	O	V	O	O	O	O	O	O	Sv	-	I	
Nitzschia bulnheimiana (Rabh.) H.L. Sm.	R	V	V	V	O	O	O	O	O	Sv	-	I-D	
Nitzschia capitellata Hust.	O	O	R	O	O	O	O	O	O	Sv	-	Sp-I	
Nitzschia communis Rabh.	O	V	O	O	O	O	O	O	O	Sv	-	Sp-I	
Nitzschia denticula Grun.	C	R	V	A	R	O	A	R	O	Sv	-	I-D	
Nitzschia filiformis (W. Sm.) Schutt	O	V	V	O	O	O	O	O	O	PP_t	S	S-I	
Nitzschia fonticola Grun.	C	R	R	C	R	R	R	V	V	Sv	-	Sp-I	
Nitzschia frustulum (Kütz.) Grun.	V	R	R	O	R	R	R	R	R	Sv	R	Sp-D	
Nitzschia frustulum var. *perminuta* Grun.	V	R	R	O	O	O	R	R	R	Sv	R	Sp-D	
Nitzschia frustulum var. *subsalina* Hust.	V	O	O	O	O	O	V	O	O	Sv	-	I	
Nitzschia hungarica Grun.	R	R	V	V	V	V	O	V	O	Sv	-	I-D	
Nitzschia ignorata Krasske	O	O	O	O	O	O	O	V	O	Sv	-	Sp	
Nitzschia insecta Hust.	O	V	O	O	O	O	O	O	O	Sv	-	I	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Nitzschia intermedia Hantz.	O	O	O	O	O	O	R	O	O	Rv	-	I-D	
Nitzschia interrupta (Reich.) Hust.	V	O	O	O	O	O	O	O	O	Sv	-	I	
Nitzschia linearis (Ag.) W. Sm.	V	O	R	O	V	R	O	O	O	Sv	T	Sp-D	
Nitzschia linearis var. *tenuis* (Kütz.) Grun.	O	O	V	O	O	O	O	O	O	Sv	T	Sp-I	
Nitzschia luzonensis Hust.	R	V	O	R	O	O	C	R	O	SSv	-	Sp-I	
Nitzschia palea (Kütz.) W. Sm.	R	R	R	R	R	R	R	R	R	Sv	-	Sp-D	Very widely distributed
Nitzschia parvula W. Sm.	O	O	V	O	O	O	O	O	O	Sv	-	Sp-I	
Nitzschia romana Grun.	V	V	V	O	V	V	V	V	V	Sv	-	I-D	
Nitzschia sigma (Kütz.) W. Sm.	V	O	O	O	O	O	O	O	O	Sv	-	I-D	
Nitzschia sigmoidea (Nitz.) W. Sm.	V	V	V	V	V	V	V	V	V	Sv	T	Sp-I	
Nitzschia sinuata var. *tabellaria* (Grun.) Grun.	V	O	O	V	O	O	V	O	O	Sv	-	Sp-I	
Nitzschia sublinearis Hust.	V	V	R	O	O	R	O	V	V	Sv	-	Sp-I	
Nitzschia thermalis (Ehr.) Auersw.	O	O	V	O	O	O	C	O	O	Sv	-	I-D	
Nitzschia tropica Hust.	V	O	O	O	O	O	O	O	O	Sv	-	I-D	
Nitzschia tryblionella Hantz.	O	O	V	O	O	O	O	O	O	Sv	-	I-D	
Nitzschia tryblionella var. *debilis* (Arn.) A. Mayer	O	O	V	O	O	O	O	O	O	Sv	-	I-D	
Nitzschia tryblionella var. *levidensis* (W. Sm.) Grun.	V	V	R	O	O	R	O	O	O	Sv	-	I-D	
Nitzschia vermicularis (Kütz.) Rabh.	O	O	V	O	O	O	O	O	O	Sv	-	S-I	
OESTRUPIA													
Oestrupia zachariasi (Reich.) Stoerm. and Yang	V	V	V	O	O	O	O	O	O	Sv	-	I-D	
Oestrupia zachariasi var. *undulata* (Schulz) Stoerm. and Yang	V	V	V	O	O	O	O	O	O	Sv	-	I-D	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
OPEPHORA													
Opephora ansata Hohn and Hellerm.	C	R	V	R	R	O	R	R	O	Ra	Sa	I-D	
Opephora martyi Hérib.	R	V	V	R	V	V	C	R	V	Ra	Sa	I-D	
PINNULARIA													
Pinnularia abaujensis (Pant.) Ross	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Pinnularia abaujensis var. *linearis* (Hust.) Patr.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Pinnularia abaujensis var. *subundulata* (A. Mayer) Patr.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Pinnularia acrosphaeria W. Sm.	V	O	O	O	O	O	O	O	O	Sv	-	I	
Pinnularia biceps Greg.	O	O	V	O	O	O	V	O	O	Sv	-	Sp-I	
Pinnularia biceps fo. *petersenii* Ross	O	O	V	O	O	O	O	O	O	Sv	-	I	Perhaps allochthonous
Pinnularia borealis Ehr.	R	O	O	O	O	O	C	V	O	Sv	-	Sp-D	Only deep localities in L. Michigan
Pinnularia brandelii Cl.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Pinnularia braunii var. *amphicephala* (A. Mayer) Hust.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Pinnularia brebissonii (Kütz.) Rabh.	V	V	V	V	O	O	O	V	O	Sv	-	Sp-I	
Pinnularia brebissonii var. *diminuta* (Grun.) Cl.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Pinnularia brevicostata Cl.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Pinnularia burkii Patr.	O	O	V	O	O	O	O	O	O	Sv	-	?	Probably allochthonous
Pinnularia divergens var. *bacillaris* (M. Perag.) Mills	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Pinnularia divergens var. *elliptica* (Grun.) Cl.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Pinnularia gentilis (Donk.) Cl.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Pinnularia globiceps var. *krockii* (Grun.) Cl.	V	O	O	O	O	O	O	O	O	Sv	-	Sp-I	
Pinnularia intermedia (Lagerst.) Cl.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Pinnularia interrupta var. *crassior* (Grun.) Cl.	V	O	V	O	O	O	O	O	O	Sv	-	Sp-I	
Pinnularia latevittata var. *domingensis* Cl.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Pinnularia legumen (Ehr.) Ehr.	0	0	V	0	0	0	0	0	0	Sv	-	?	Probably allochthonous
Pinnularia leptosoma (Grun.) Cl.	0	0	V	0	0	0	0	0	0	Sv	-	?	Probably allochthonous
Pinnularia leptosoma fo. *erlangensis* A. Mayer	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Pinnularia major (Kütz.) Rabh.	0	0	V	0	0	0	0	0	0	Sv	-	Sp-I	Probably allochthonous
Pinnularia mesolepta (Ehr.) W. Sm.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Pinnularia microstauron (Ehr.) Cl.	V	0	0	V	0	0	V	0	0	Sv	-	I-Sp	
Pinnularia microstauron var. *biundulata* O. Müll.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Pinnularia molaris (Grun.) Cl.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Pinnularia nodosa (Ehr.) W. Sm.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Pinnularia obscura Krasske	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Pinnularia ruttneri Hust.	0	0	V	0	0	0	0	0	0	Sv	-	D	
Pinnularia semicruciata A. Cl.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Pinnularia subrostrata A. Cl.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Pinnularia substomatophora Hust.	0	0	0	0	0	0	R	0	0	Sv	-	Sp	
Pinnularia tenuis Greg.	0	0	0	0	0	0	R	0	0	Sv	-	Sp	
Pinnularia tenuis var. *interrupta* (Font.) A. Cl.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Pinnularia termitina (Ehr.) Patr.	V	0	0	0	0	0	R	0	0	Sv	-	Sp-I	
Pinnularia tibetana Hust.	V	0	0	0	0	0	0	0	0	Sv	-	Sp-I	Historic L. Michigan sample only
Pinnularia undulata Greg.	V	0	0	0	0	0	0	0	0	Sv	-	Sp-I	
Pinnularia undulata var. *subundulata* Grun.	0	0	0	0	0	0	R	0	0	Sv	-	Sp	
Pinnularia viridis (Nitz.)Ehr.	R	0	0	R	0	0	0	V	0	Sv	-	I-Sp	
Pinnularia viridis var. *commutata* (Grun.) Cl.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
PLAGIOTROPIS													
Plagiotropis lepidoptera var. *proboscidea* (Cl.) Reim.	V	V	R	V	V	R	O	O	O	SSv	T	I	
PLEUROSIGMA													
Pleurosigma delicatulum W. Sm.	V	O	O	O	O	O	O	O	O	Sv	-	D	
RHOICOSPHENIA													
Rhoicosphenia curvata (Kütz.) Grun.	C	C	A	C	C	A	V	R	C	PPa	Ra	S-I	
Rhoicosphenia curvata var. *subacuta* M. Schmidt	O	O	V	O	O	O	O	O	O	Ra	PPa	S-I	
RHOPALODIA													
Rhopalodia gibba (Ehr.) O. Müll.	C	R	R	C	R	R	R	R	V	PPa	S	I-D	
Rhopalodia gibba var. *ventricosa* (Kütz.) H. Perag. and M. Perag.	R	V	O	O	O	O	O	O	O	PPa	S	D-I	
Rhopalodia gibberula (Ehr.) O. Müll.	O	V	V	O	O	O	O	V	O	PPa	S	S-I	
Rhopalodia parallela (Grun.) O. Müll.	O	O	O	O	O	O	V	O	O	PPa	S	Sp-I	
STAURONEIS													
Stauroneis acutiuscula M. Perag. and Hérib.	V	R	V	V	R	V	V	V	V	Sv	-	I-D	
Stauroneis agrestis Peters.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	Aerophytic, possibly allochthonous
Stauroneis anceps Ehr.	V	V	V	O	O	O	O	O	O	Sv	-	Sp-I	
Stauroneis anceps var. *americana* Reim.	O	O	O	O	O	O	V	V	O	Sv	-	Sp-I	
Stauroneis anceps var. *hyalina* Brun and M. Perag.	O	V	O	O	O	O	O	O	O	Sv	-	I	Possibly allochthonous
Stauroneis anceps var. *siberica* Grun.	V	V	O	O	O	O	O	O	O	Sv	-	I	
Stauroneis anceps fo. *gracilis* Rabh.	O	O	O	O	O	O	V	O	O	Sv	-	Sp	
Stauroneis dilatata Ehr.	V	O	O	V	O	O	R	V	O	Sv	-	Sp-I	Historic L. Michigan samples only

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Stauroneis dilatata var. *baicalensis* Skv. and Meyer	V	0	0	0	0	0	R	V	0	Sv	-		
Stauroneis kriegeri Patr.	0	0	0	0	0	0	R	V	0	Sv	-	Sp-I	
Stauroneis kriegeri fo. *undulata* Hust.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Stauroneis livingstonii Reim.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
Stauroneis nobilis var. *baconiana* (Stodd.) Reim.	V	0	0	0	0	0	0	0	0	Sv	-	I-D	
Stauroneis phoenicenteron (Nitz.) Ehr.	V	0	0	V	0	0	V	V	0	Sv	-	I-D	
Stauroneis phoenicenteron var. *brevis* Dippel	V	0	0	0	0	0	0	0	0	Sv	-	I-D	Historic samples only
Stauroneis phoenicenteron fo. *gracilis* (Ehr.) Hust.	0	0	0	0	0	0	V	0	0	Sv	-	Sp-I	
Stauroneis phoenicenteron var. *lanceolata* (Kütz.) Brun	V	0	0	0	0	0	V	V	0	Sv	-	Sp-I	
Stauroneis smithii Grun.	V	0	V	V	0	0	V	V	0	Sv	-	Sp-I	
Stauroneis smithii var. *minima* Haworth	0	0	0	0	0	0	V	0	0	Sv	-	Sp	Most other reports fossil
STENOPTEROBIA													
Stenopterobia intermedia (Lewis) V.H.	0	0	0	0	0	0	V	0	0	Sv	-	Sp	
SURIRELLA													
Surirella angusta Kütz.	V	R	R	V	R	D	V	V	V	Sv	T	I-D	Abundant in winter plankton in polluted waters
Surirella angusta var. *panduriformis* W. Sm.	V	0	0	0	0	0	0	0	0	Sv	-	I-D	Only historic L. Michigan samples
Surirella biseriata Bréb. and Godey	0	0	0	0	0	0	V	V	0	Sv	T	Sp-D	
Surirella biseriata var. *bifrons* (Ehr.) Hust.	V	0	0	V	0	0	V	V	0	Sv	T	Sp-D	More abundant in historic L. Michigan samples
Surirella delicatissima Lewis	0	0	0	V	0	0	V	0	0	Sv	-	Sp-I	
Surirella elegans Ehr.	V	0	0	0	0	0	0	0	0	Sv	-	I-D	Historic L. Michigan samples only
Surirella guatemalensis Ehr.	0	0	V	0	0	0	0	0	0	Sv	-	I-D	
Surirella linearis W. Sm.	V	0	0	V	0	0	V	V	0	Sv	T	I-D	More abundant in historic L. Michigan samples
Surirella linearis var. *constricta* (Ehr.) Grun.	V	0	0	V	0	0	V	V	0	Sv	T	I-D	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	II	III	Lake Huron I	II	III	Lake Superior I	II	III	Primary habitats	Secondary habitats	Depth range	Notes
Surirella linearis var. *helvetica* (Brun) Meist.	V	O	O	O	O	O	V	V	O	Sv	T	I-D	
Surirella ovalis Bréb.	O	V	R	O	V	C	O	O	O	Sv	T	I-D	Halophilic
Surirella ovata Kütz.	V	V	R	V	V	C	O	O	O	Sv	T	I-D	Common in plankton of polluted streams
Surirella ovata var. *pinnata* (W. Sm.) Rabh.	V	V	C	V	V	C	O	O	O	Sv	T	I-D	Common in plankton of polluted streams
Surirella ovata var. *salina* (W. Sm.) Rabh.	O	O	O	O	O	R	O	O	O	Sv	T	I-D	Saginaw Bay only
Surirella robusta var. *splendida* (Ehr.) V.H.	V	O	O	O	O	O	O	O	O	Sv	T	I-D	
Surirella tenera var. *nervosa* A.S.	O	O	V	O	O	O	O	O	O	Sv	T	I-D	
Surirella tenuissima Hust.	O	O	V	O	O	O	O	O	O	Sv	-	I	
SYNEDRA													
Synedra acus Kütz.	C	R	R	R	R	V	C	R	R	Ra	S	S-I	
Synedra capitata Ehr.	V	O	V	R	O	O	V	O	O	Ra	PPa	S-I	
Synedra fasciculata (Ag.) Kütz.	O	O	R	O	O	V	O	O	O	Ra	PPa	I	Halophilic
Synedra goulardi Brêb.	O	O	V	O	O	O	O	O	O	Ra	PPa	S-I	Probably allochthonous
Synedra parasitica (W. Sm.) Hust.	V	V	V	O	V	V	V	V	O	Ra	PPa	S-I	
Synedra parasitica var. *subconstricta* (Grun.) Hust.	V	V	V	O	O	O	V	V	O	Ra	PPa	S-I	
Synedra pulchella Ralfs	O	O	R	O	O	R	O	O	O	Ra	PPa	S-I	Halophilic
Synedra rumpens Kütz.	R	R	V	R	V	V	C	R	V	Ra	PPa	S-I	
Synedra rumpens var. *familiaris* (Kütz.) Hust.	O	O	O	O	O	O	V	O	O	Ra	PPa	Sp	
Synedra rumpens var. *fragilarioides* Grun.	R	V	V	R	V	O	C	R	R	Ra	PPa	S-I	
Synedra rumpens var. *meneghiniana* Grun.	V	O	O	O	O	O	O	O	O	Ra	PPa	I	
Synedra tenera W. Sm.	C	R	O	C	R	O	C	R	O	Ra	T	S-I	
Synedra ulna (Nitz.) Ehr.	C	C	C	C	C	C	D	C	C	Ra	PPa	S-I	Very widely distributed
Synedra ulna var. *aequalis* (Kütz.) Hust.	O	V	V	O	O	O	O	O	O	Ra	PPa	S-I	

(continued)

TABLE 1 (continued)

Name	Lake Michigan I	Lake Michigan II	Lake Michigan III	Lake Huron I	Lake Huron II	Lake Huron III	Lake Superior I	Lake Superior II	Lake Superior III	Primary habitats	Secondary habitats	Depth range	Notes
Synedra ulna var. *amphirhynchus* (Ehr.) Grun.	R	V	O	R	V	O	R	V	O	Ra	PPa	S-I	More abundant in historic L. Michigan samples
Synedra ulna var. *biceps* (Kütz.) Kirchn.	O	V	V	O	O	O	O	O	O	Ra	PPa	S-I	
Synedra ulna var. *claviceps* Hust.	R	C	R	R	R	R	V	V	V	Ra	PPa	S-I	
Synedra ulna var. *constricta* Venkt.	V	V	V	V	O	O	V	O	O	Ra	PPa	S-I	
Synedra ulna var. *oxyrhynchus* (Kütz.) V.H.	R	V	O	R	V	O	C	V	O	Ra	PPa	S-I	
Synedra ulna var. *oxyrhynchus* f. *mediocontracta* (Forti) Hust.	R	O	O	O	O	O	O	O	O	Ra	PPa	S-I	
Synedra ulna var. *spathulifera* (Grun.) V.H.	R	V	O	C	V	O	C	V	O	Ra	PPa	S-I	
Synedra ulna var. *subaequalis* (Grun.) V.H.	O	O	V	O	O	O	O	O	O	Ra	PPa	S-I	
Synedra vaucheriae (Kütz.) Kutz.	C	C	D	O	R	D	O	O	O	Ra	PPa	S-I	
Synedra vaucheriae var. *capitellata* (Grun.) Cl.	C	R	O	C	R	O	C	R	R	Ra	PPa	S-I	
Synedra vaucheriae var. *truncata* (Grev.) Grun.	V	O	O	O	O	O	O	O	O	Ra	PPa	S-I	
TABELLARIA													
Tabellaria flocculosa (Roth) Kütz.	A	C	R	A	C	R	D	C	R	Ra	S	S-I	

APPENDIX I

Plates. Benthic diatom taxa are pictured and the corresponding collection locality is noted. All specimens are presented at 1000X and a 10 µm bar is given on photomicrograph number 2 of each plate. Voucher specimens are housed at the Great Lakes Research Division, University of Michigan.

PLATE I

1. *Melosira undulata*, valve view (VV), Lake Superior.
2. *M. undulata* var. *normannii*, VV, Lake Michigan.
3. *M. varians*, Lake Michigan.
4. *Fragilaria constricta* fo. *stricta*, Lake Superior.
5. *F. leptostauron* var. *fossilis*, Lake Michigan.
6. *Opephora martyi*, Lake Michigan.
7. *Synedra capitata*, Lake Huron.
8. *S. ulna* var. *spathulifera*, Lake Michigan.
9. *S. pulchella*, Lake Michigan.
10. *Diatoma vulgare* var. *linearis*, Lake Michigan.
11. *D. anceps*, Lake Superior.
12. *Eunotia incisa*, Lake Michigan.
13. *Tabellaria flocculosa*, Lake Superior.
14. *Achnanthes clevei* var. *rostrata*, pseudoraphe valve (PRV), Lake Michigan.
15. *A. lanceolata* var. *haynaldii*, raphe valve (RV), Lake Michigan.
16. *Eunotia praerupta*, Lake Michigan.
17. *E. formica*, Lake Michigan.
18. *Achnanthes lanceolata* var. *abbreviata*, PRV, Lake Michigan.
19. *A. hauckiana* var. *rostrata*, PRV, Lake Michigan.
20. *A. hauckiana* var. *rostrata*, RV, Lake Michigan.
21. *Rhoicosphenia curvata*, Lake Huron.
22. *Cocconeis disculus*, PRV, Lake Michigan.
23. *C. placentula* var. *rouxii*, RV, Lake Superior.
24. *C. pediculus*, post-auxospore, RV, Lake Huron.

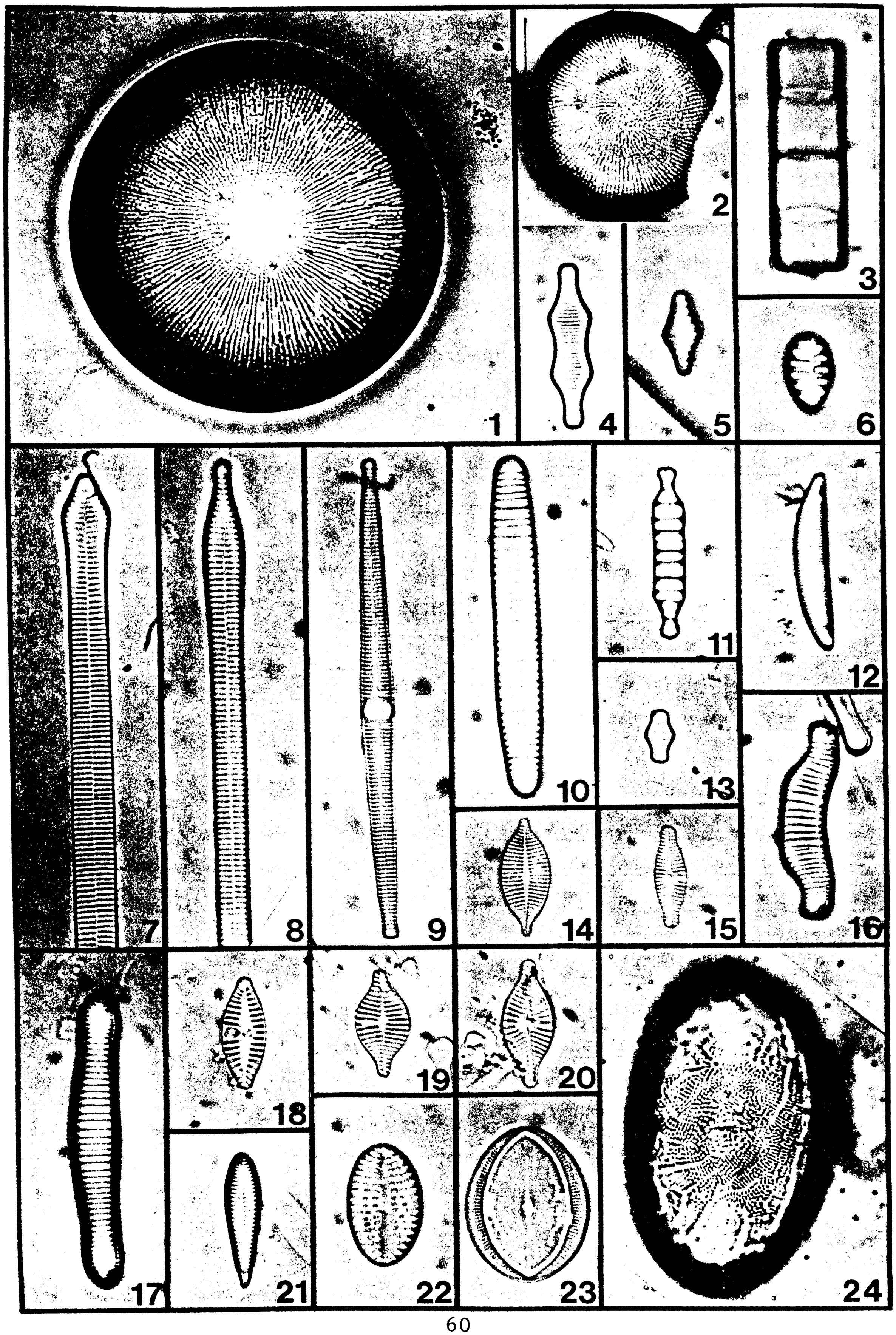
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PLATE II

1. Mastogloia smithii var. amphicephala, Lake Michigan.
2. Anomoeoneis follis, Lake Superior.
3. Frustulia rhomboides var. amphipleuroides, Lake Michigan.
4. Gyrosigma spencerii var. curvula, Lake Michigan.
5. Stauroneis dilatata var. baicalensis, Lake Michigan.
6. Capartogramma crucicula, Lake Michigan.
7. Stauroneis phoenicenteron var. lanceolata, Lake Michigan.
8. Oestrupia zachariasi var. undulata, Lake Michigan.
9. Neidium sp., Lake Superior.
10. Diploneis finnica, Lake Superior.
11. Diploneis elliptica var. pygmaea, Lake Michigan.
12. Caloneis ventricosa var. minuta, Lake Michigan.
13. C. nubicola, Lake Superior.
14. Neidium hitchcockii, Lake Superior.
15. N. sacoense, Lake Michigan.
16. Caloneis lewisii, Lake Superior.
17. C. alpestris, Lake Michigan.
18. C. amphisbaena, Lake Michigan.
19. Pinnularia nodosa, Lake Superior.
20. P. brandelii, Lake Superior.
21. P. borealis, Lake Michigan.

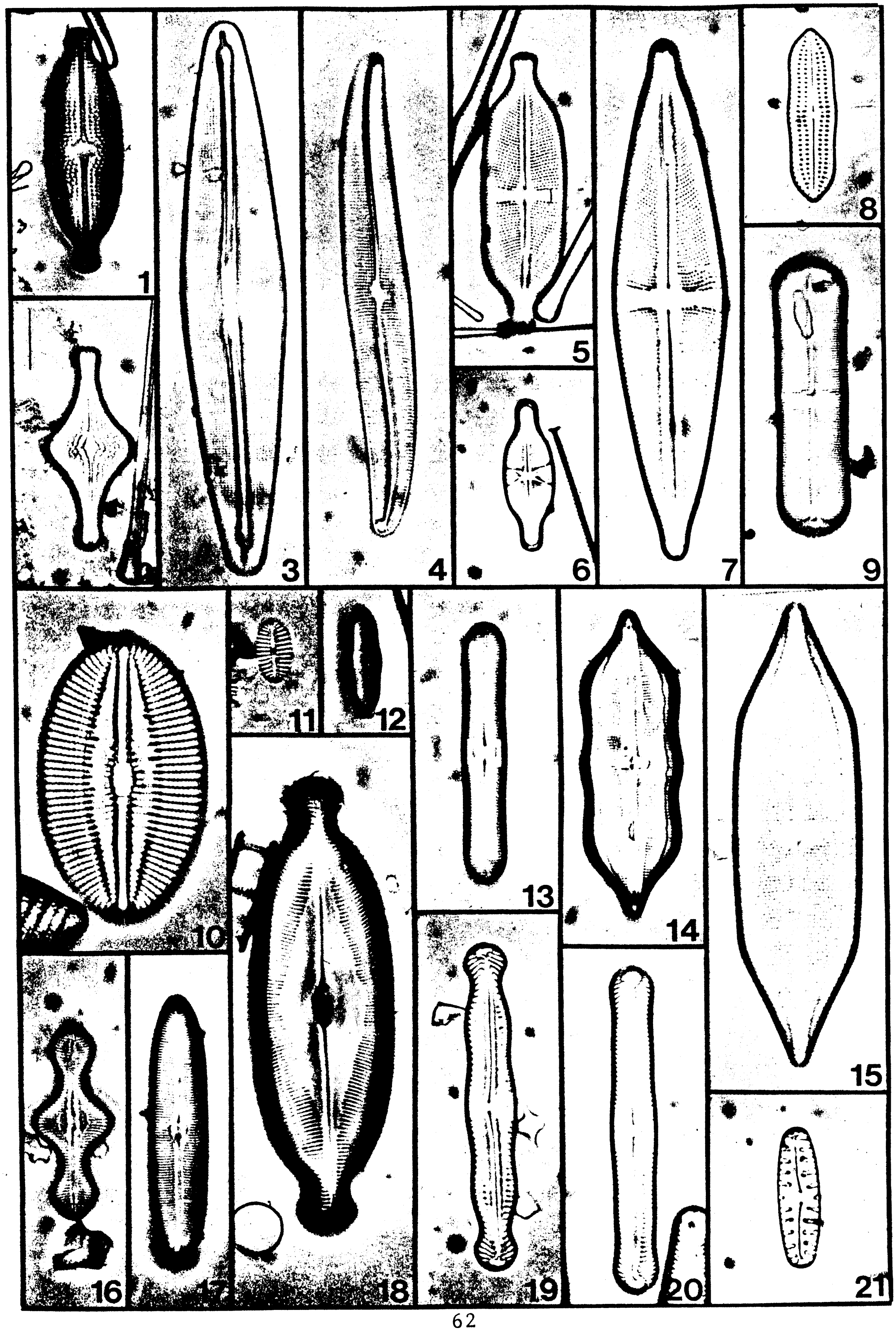
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PLATE III

1. *Navicula pygmaea*, Lake Michigan.
2. *N.* sp., Lake Michigan.
3. *N. amphibola* var. *perrieri*, Lake Michigan.
4. *N. lacustris*, Lake Michigan.
5. *N. pseudoscutiformis*, Lake Superior.
6. *N. cocconeiformis*, Lake Michigan.
7. *N. scutelloides*, Lake Michigan.
8. *N. terminata*, Lake Michigan.
9. *N. mutica* var. *undulata*, Lake Superior.
10. *N. jaernefeltii*, Lake Superior.
11. *N. subhamulata*, Lake Michigan.
12. *N. integra*, Lake Michigan.
13. *N. farta*, Lake Michigan.
14. *N. lanceolata* var. *cymbula*, Lake Michigan.
15. *N. bacillum*, Lake Michigan.
16. *N. cuspidata*, Lake Michigan.
17. *N. americana*, Lake Superior.
18. *N. levanderi*, Lake Michigan.
19. *N. reinhardtii*, Lake Michigan.
20. *N. reinhardtii* var. *elliptica*, Lake Michigan.
21. *N. wittrockii*, Lake Michigan.
22. *N. wittrockii*, Lake Michigan.
23. *N. oblonga*, Lake Michigan.
24. *N. tuscula*, Lake Michigan.
25. *N. aurora*, Lake Michigan.

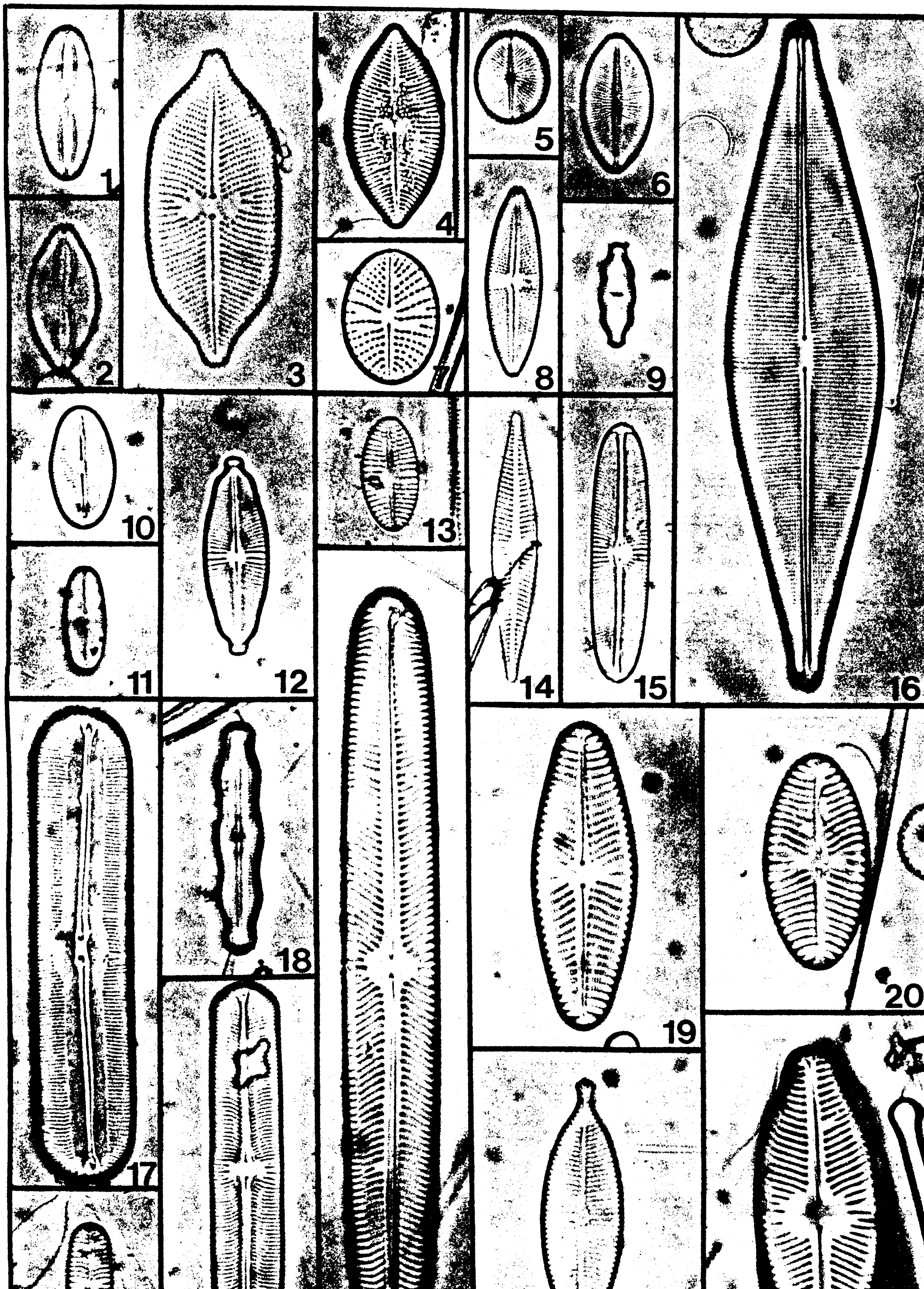
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PLATE IV

1. *Gomphonema acuminatum* var. *coronata*, Lake Michigan.
2. *G. sphaerophorum*, Lake Huron.
3. *G. truncatum*, Lake Michigan.
4. *G. truncatum* var. *capitatum*, Lake Michigan.
5. *G. grovei*, Lake Michigan.
6. *G. abbreviatum* var. *inflata*, Lake Michigan.
7. *Gomphoneis eriense*, Lake Michigan.
8. *G. herculeana*, Lake Huron.
9. *Didymosphenia geminata*, Lake Superior.
10. *Cymbella cistula* var. *gibbosa*, Lake Huron.
11. *Amphora calumetica*, Lake Michigan.
12. *A. hemicycla*, Lake Michigan.
13. *A. michiganensis*, Lake Michigan.
14. *A. huronensis*, Lake Huron.
15. *Cymbella sinuata* var. *antiqua*, Lake Huron.
16. *C. triangulatum*, Lake Michigan.

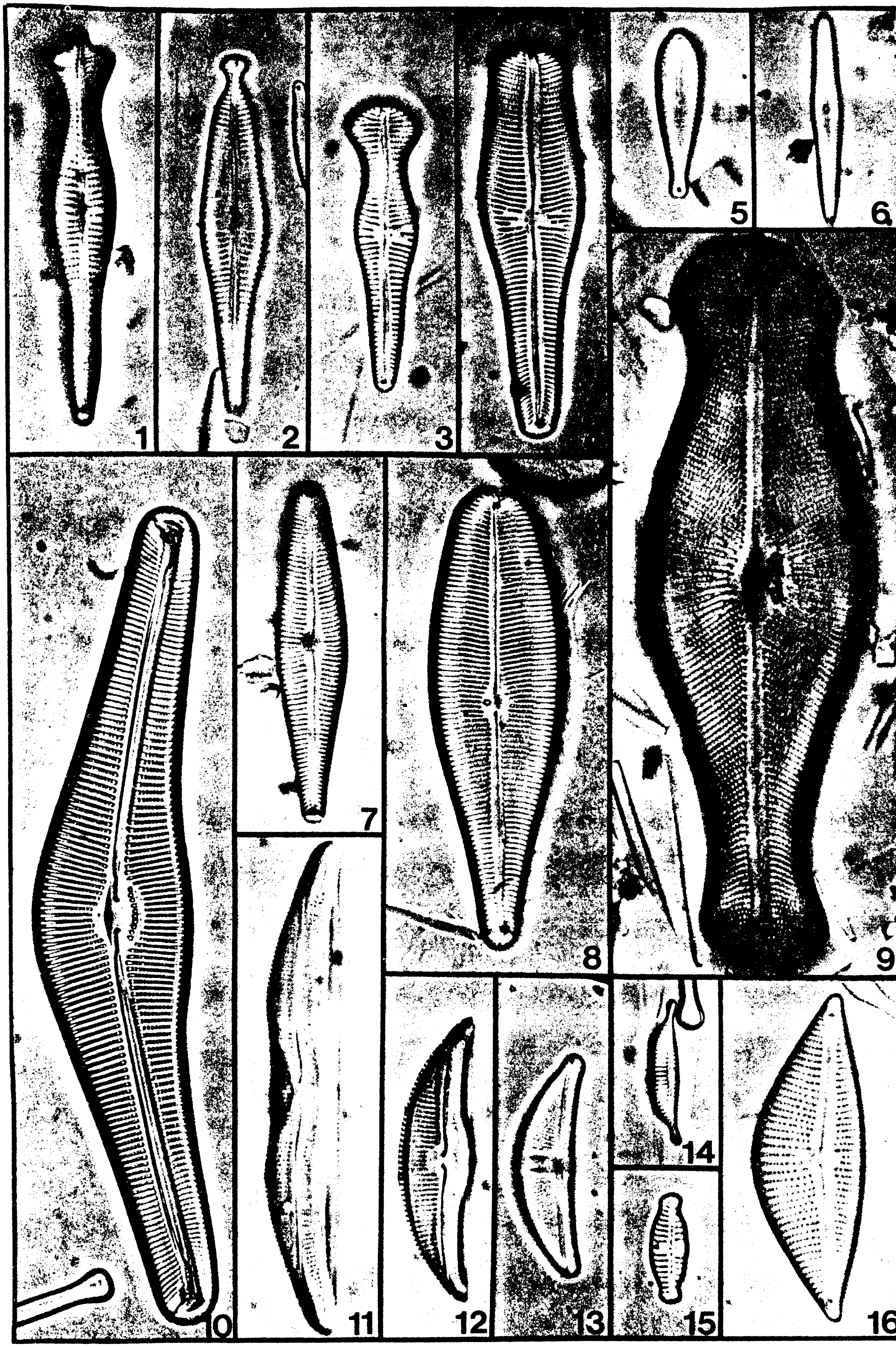
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PLATE V

1. Nitzschia acula, Lake Michigan.
2. N. palea, Lake Michigan.
3. N. denticula, Lake Huron.
4. N. tryblionella var. levidensis, Lake Michigan.
5. N. tryblionella, Lake Michigan.
6. Bacillaria paxillifer, Lake Michigan.
7. Nitzschia angustata var. acuta, Lake Huron.
8. N. parvula, Lake Michigan.
9. N. denticula, Lake Michigan.
10. N. sinuata var. tabellaria, Lake Michigan.
11. N. amphibia, Lake Michigan.
12. N. sp., Lake Michigan.
13. N. luzonensis, Lake Michigan.
14. Surirella angusta, Lake Michigan.
15. Rhopalodia gibba var. ventricosa, Lake Michigan.
16. Nitzschia romana, Lake Michigan.
17. Denticula tenuis var. crassula, Lake Michigan.
18. Hantzschia amphioxys, Lake Michigan.
19. Surirella ovata, Lake Michigan.
20. S. angusta, Lake Michigan.
21. Stenopterobia intermedia, Lake Superior.
22. Rhopalodia gibberula, Lake Michigan.
23. R. gibba, Lake Michigan.

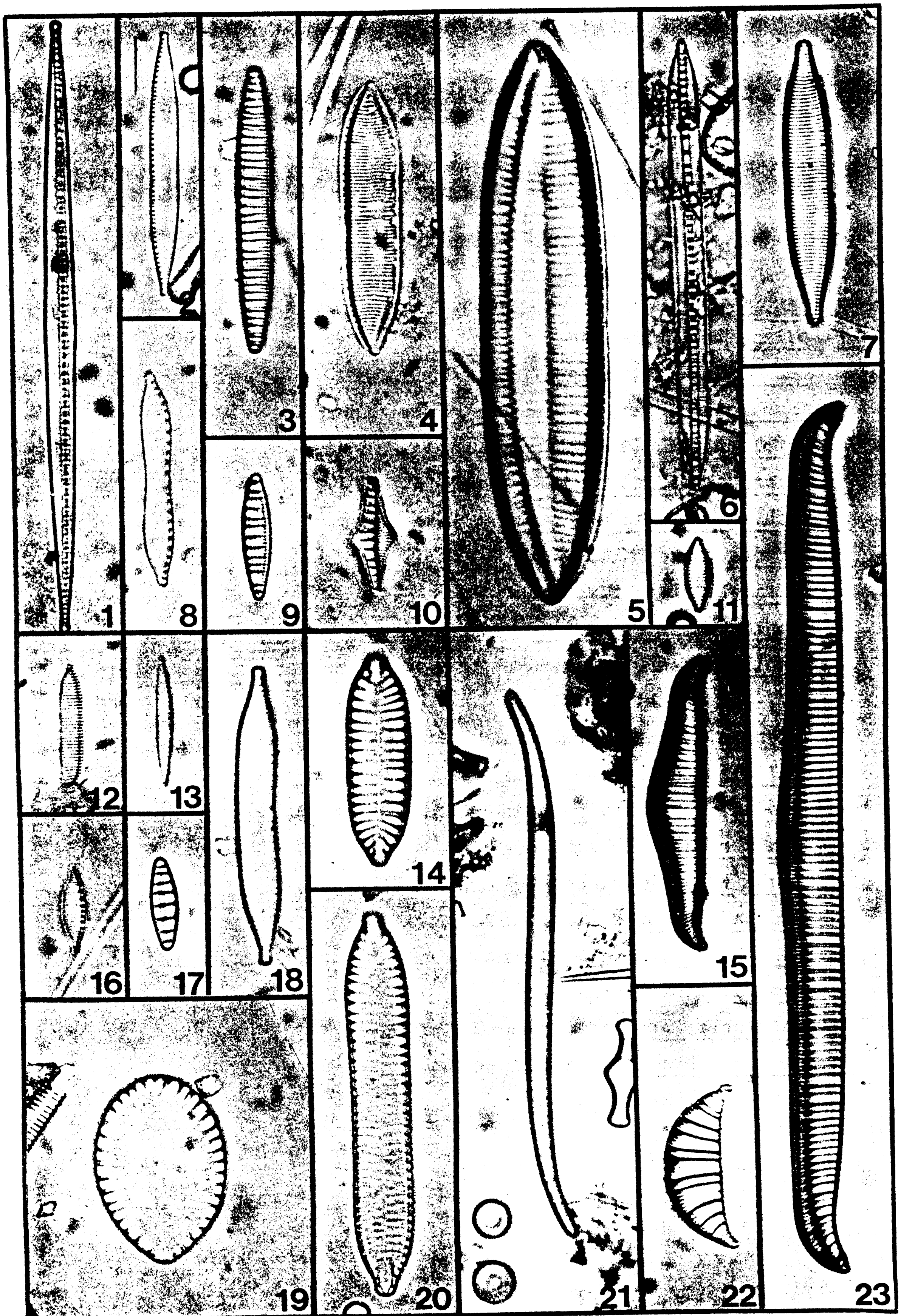
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PLATE VI

1. Cymatopleura solea var. apiculata, Lake Michigan.
2. Surirella robusta var. splendida, Lake Michigan.
3. S. guatemalensis, Lake Michigan.
4. Plagiotropis lepidoptera var. proboscidea, Lake Michigan.

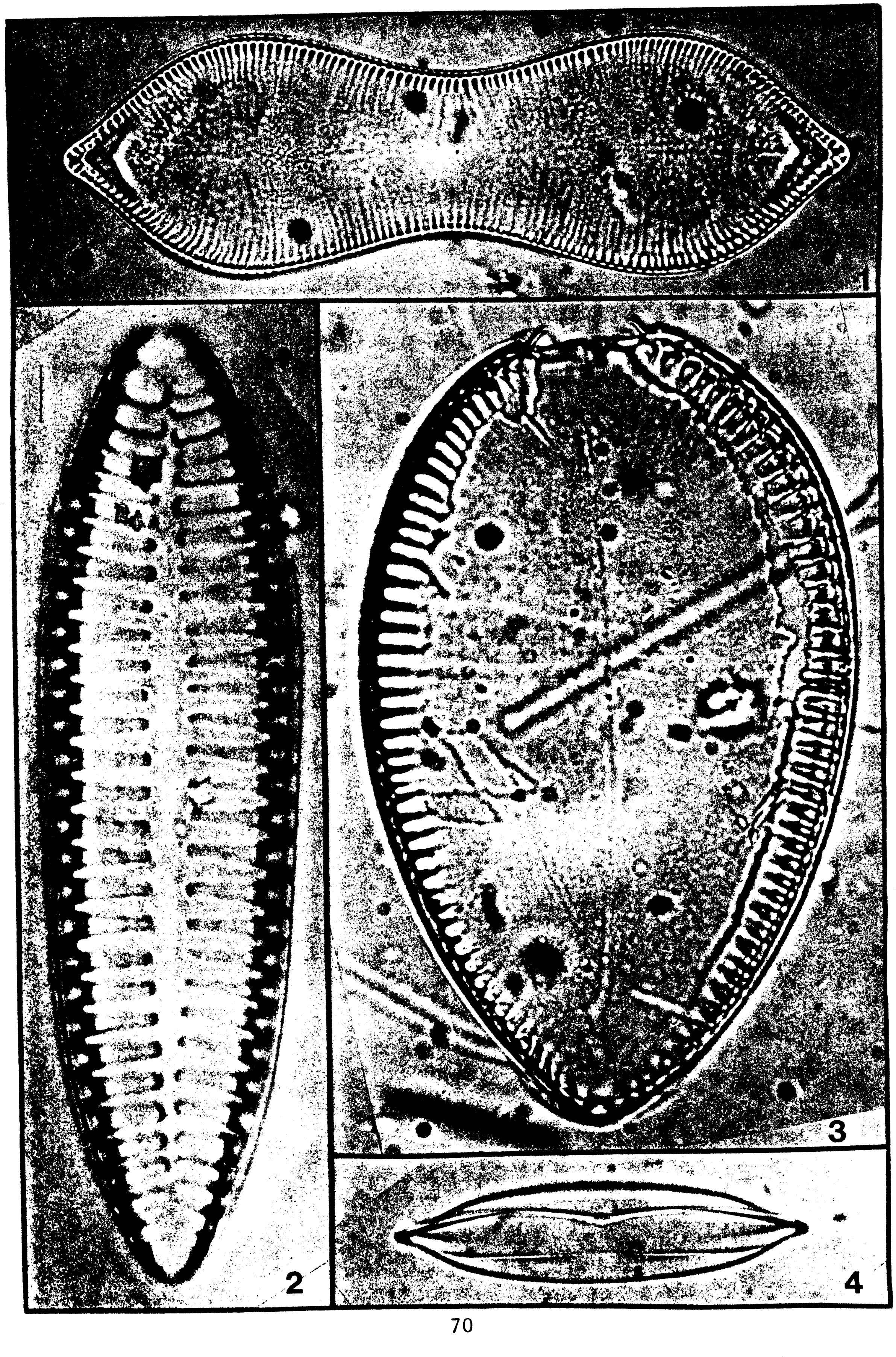
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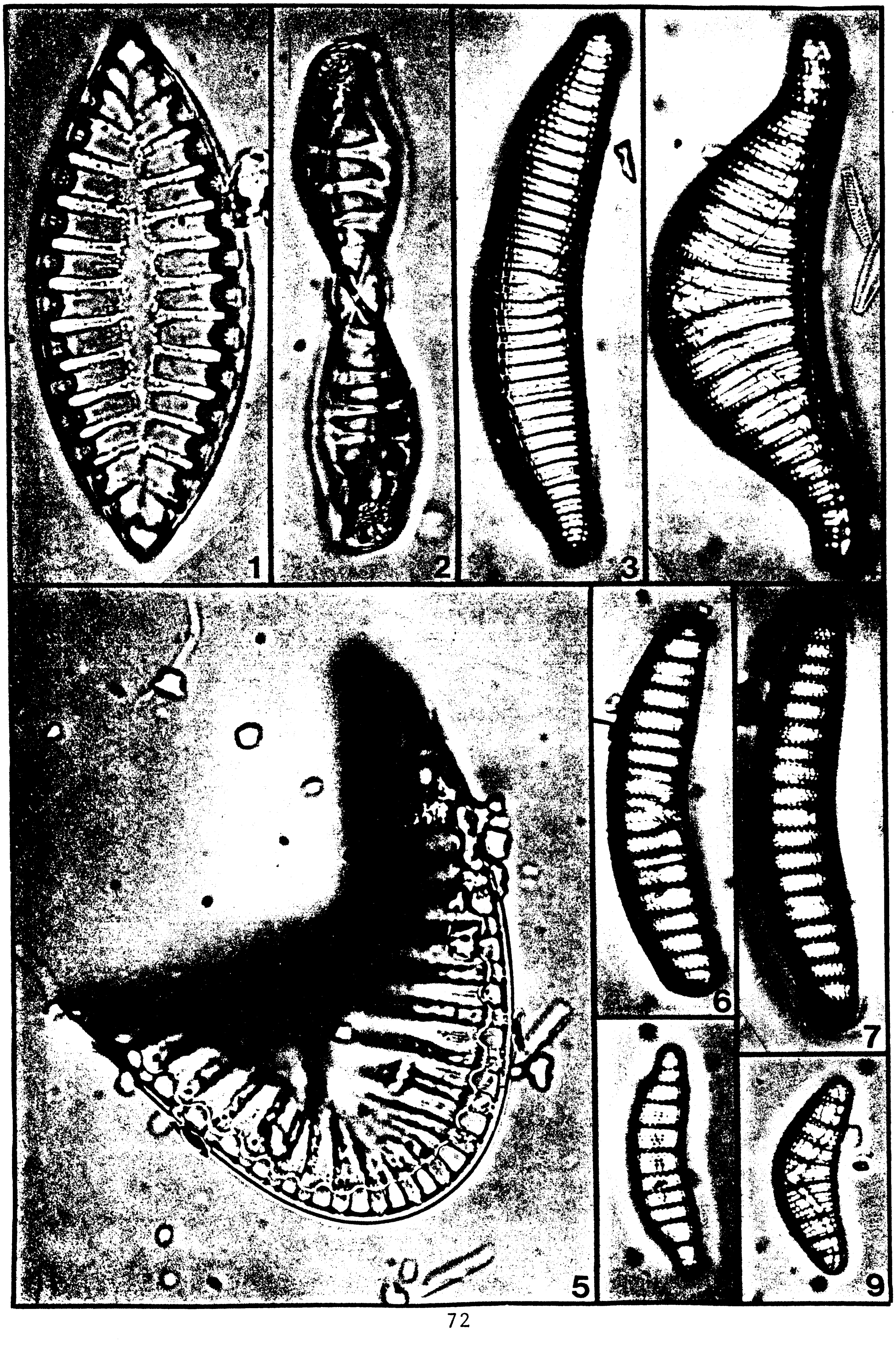
PLATE VII

1. Surirella biseriate var. bifrons, Lake Huron.
2. Entomoneis ornata, Lake Michigan.
3. Epithemia turgida, Lake Michigan.
4. E. smithii, Lake Michigan.
5. Campylodiscus noricus var. hibernica, Lake Huron.
6. Epithemia adnata, Lake Michigan.
7. E. adnata var. saxonica, Lake Michigan.
8. E. adnata var. porcellus, Lake Michigan.
9. E. argus var. alpestris, Lake Michigan.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16. ABSTRACT

The upper Great Lakes contain a diverse array of benthic algal communities. Characteristic communities occupy substrates from the supralittoral to depths in excess of 30 m. Diatoms are the dominant taxonomic group present in terms of numbers, and usually in terms of biomass, except in eutrophic areas. Communities in areas receiving minimal direct anthropogenic impact are extremely diverse in terms of both species richness and population evenness. The populations which comprise these communities are generally reported from extremely oligotrophic habitats. A significant number of populations found in undisturbed habitats in the upper Great Lakes have not been previously reported from North America. Benthic communities in more eutrophic areas are characterized by a greater abundance of eurytopic and widely distributed taxa. Many of these species are familiar elements of the floras of smaller, mesotrophic to eutrophic lakes. The communities of directly impacted areas contain a more limited suite of very tolerant populations, usually occurring in high abundance.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Algae, Water Quality	Benthic Algae, Lake Michigan, Huron, and Superior	06F

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